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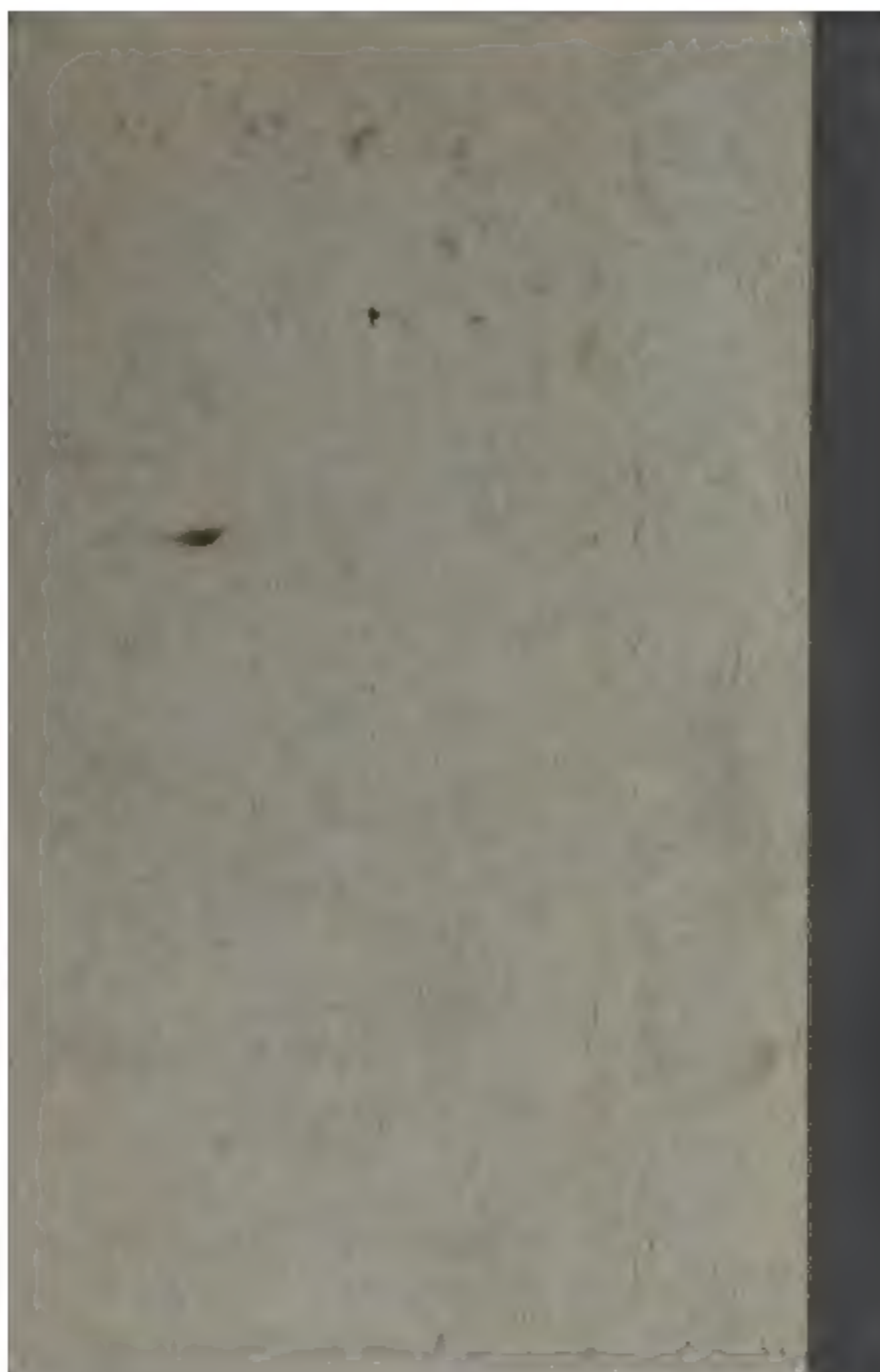
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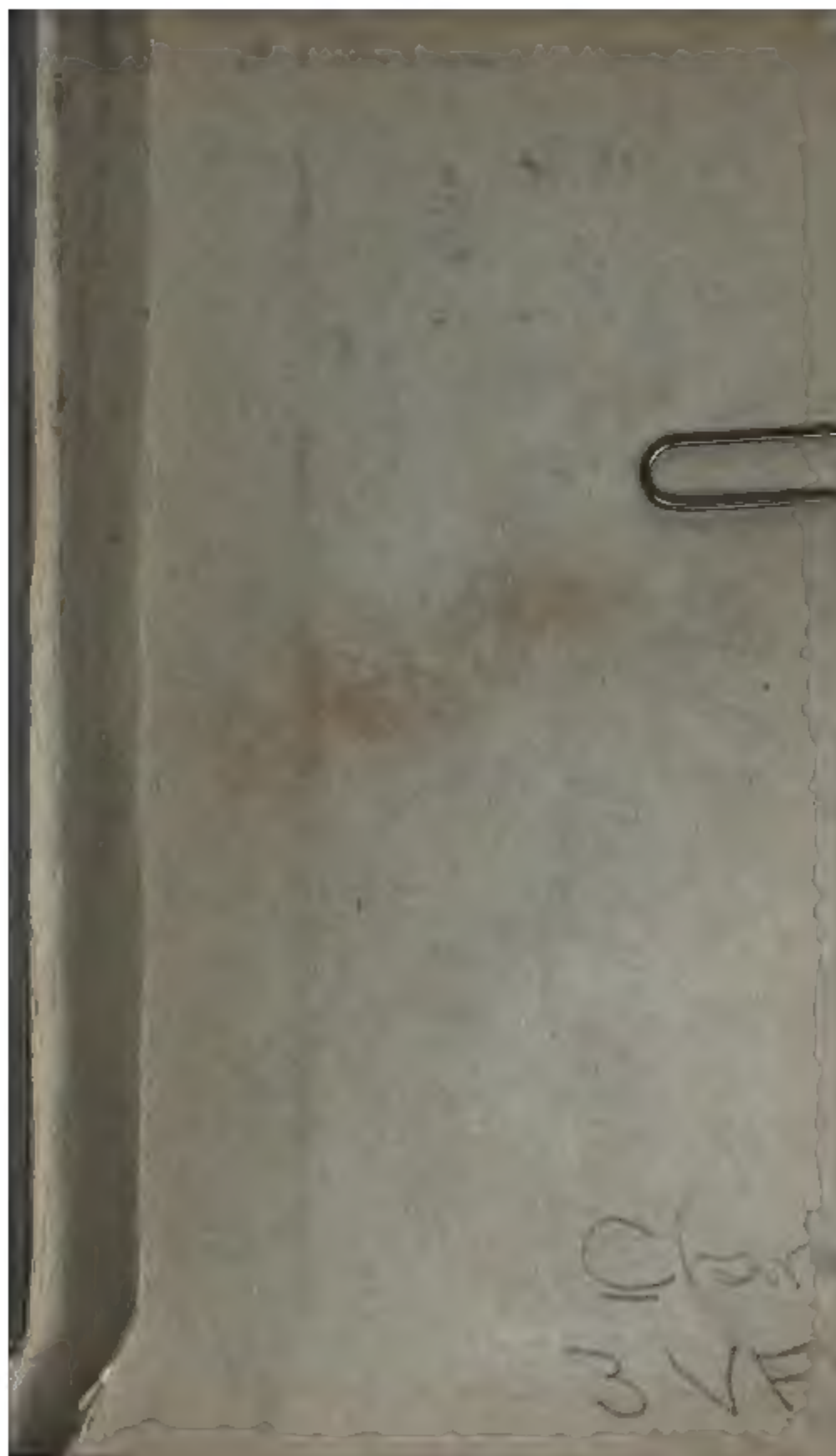
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THE
MECHANICAL ENGINEER'S
POCKET-BOOK

OF

Tables, Formulæ, Rules, and Data

A HANDY BOOK OF REFERENCE FOR
DAILY USE IN ENGINEERING PRACTICE

BY

D. KINNEAR CLARK, M. INST. C. E.

HON. MEM. AMERICAN SOCIETY OF MECHANICAL ENGINEERS

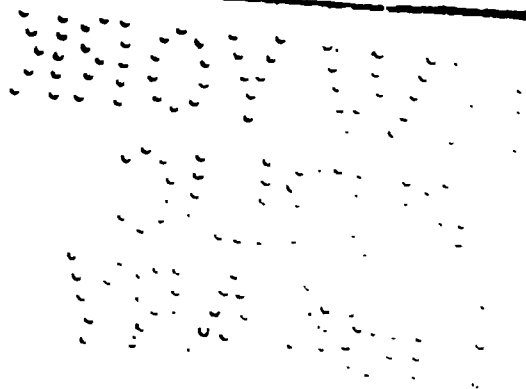
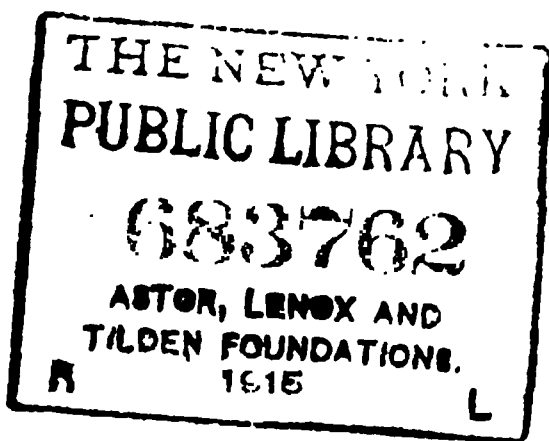
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PREFACE.

MANY works of the POCKET-BOOK class have already been published for the use of professional men ; but none of those with which I am acquainted has been compiled expressly with a view to the requirements of the Mechanical Engineer.

This POCKET-BOOK has accordingly been prepared for the purpose of shortening the calculations and other intricate mental operations which are amongst the daily recurring needs of mechanical men. To meet such needs, there will be found in the following pages about 350 Tables of results of calculations, relating to the principal branches of mechanical practice, which have either been compiled anew, or drawn from various sources. There are, in addition, about 500 Formulæ and Rules, with Data of general utility, classified for ready reference. By their aid, any a weary search in larger and more ambitious works may be dispensed with, and the labour of calculation greatly abridged, or even entirely avoided. I do not lay especial claim in these pages to originality, for much of the matter of the book is necessarily common property. I have, nevertheless, contributed my original tables, formulæ, and data, hercin published for the first time. And with regard to all matter of the work, I have spared no pains, on the one hand, to select such questions as the mechanical engineer would probably *most* desire to find elucidated ; and *the other*, to draw my material from the best and *trustworthy* sources.

Besides the usual indispensable mathematical tables, and rules for measurement of surfaces and solids, full tables of English weights and measures, with French metric equivalents, are given ; tables of French metric weights and measures, with equivalent English values, are also given.

Many useful tables are given of the weights and strength of bars, sheets, beams, joists, girders, tubes, pipes, bolts and nuts, cylinders, nails, chains, and other manufactured pieces. For the strength of materials, a variety of experimental evidence is given, with many new formulæ and tables. Heat and its applications have been fully considered in various aspects. The best proportions of steam engines, simple and compound, are discussed ; together with pumping engines, water power, and compressed-air power.

I am indebted to Mr. H. R. Kempe, A.M.I.C.E., for his assistance in the preparation of the section on Electrical Engineering ; and in various sections acknowledgments will be found duly made of my indebtedness to other authorities.

I am in hopes that the variety of matter here presented will meet all reasonable requirements of practical men in such a work, and enable them to dispense very largely with exterior aid.

At the same time, I shall be glad to avail myself of the hints or suggestions of mechanical men using the book, with a view to improve and to perfect its contents ; and I shall receive with pleasure communications which may be made to me from any quarter with that object.

D. K. CLARK.

LONDON, November, 1891.

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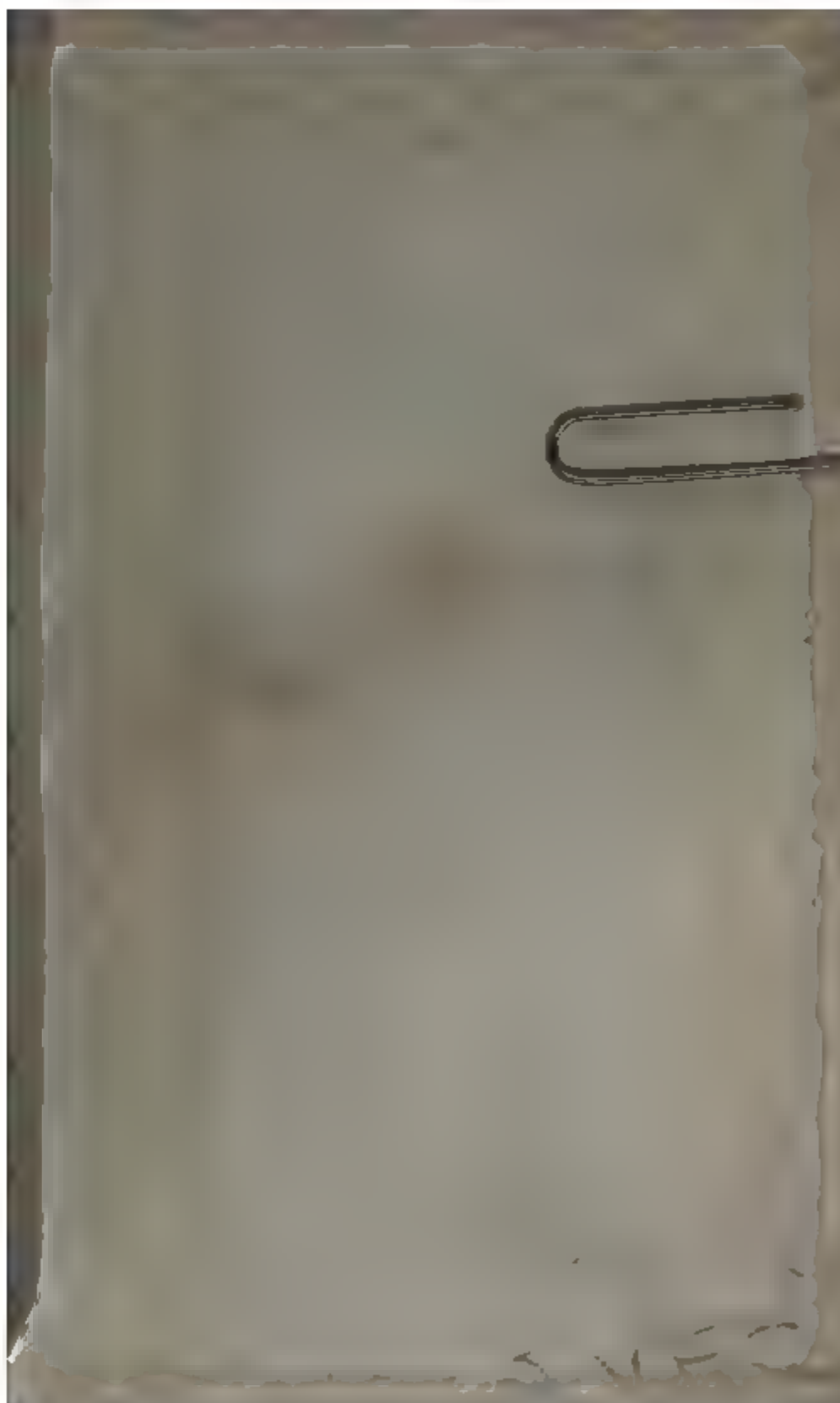
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Circular Area.	Square.	Cube.	Square Root.	Cube Root.
33979.47	43,264	8,998,912	14.422	5.924
34306.98	43,681	9,123,329	14.456	5.934
34636.06	44,100	9,261,000	14.491	5.943
34966.71	44,521	9,393,931	14.525	5.953
35298.94	44,944	9,528,128	14.560	5.962
35632.73	45,369	9,663,597	14.594	5.972
35968.09	45,796	9,800,344	14.628	5.981
36305.03	46,225	9,938,375	14.662	5.990
36643.61	46,656	10,077,696	14.696	6.000
36983.61	47,089	10,218,313	14.730	6.009
37325.26	47,524	10,360,232	14.764	6.018
37668.48	47,961	10,503,459	14.798	6.027
38013.27	48,400	10,648,000	14.832	6.036
38359.63	48,841	10,793,861	14.866	6.045
38707.56	49,284	10,941,048	14.899	6.055
39057.07	49,729	11,089,567	14.933	6.064
39408.14	50,176	11,239,424	14.966	6.073
39760.78	50,625	11,390,625	15.000	6.082
40115.00	51,076	11,543,176	15.033	6.091
40470.78	51,529	11,697,083	15.066	6.100
40828.14	51,984	11,852,352	15.099	6.109
41187.07	52,441	12,008,989	15.132	6.118
41547.56	52,900	12,167,000	15.165	6.126
41909.63	53,361	12,326,391	15.198	6.135
42273.27	53,824	12,487,168	15.231	6.144
42638.48	54,289	12,649,337	15.264	6.153
43005.26	54,756	12,812,904	15.297	6.162
43373.61	55,225	12,977,875	15.329	6.171
43743.54	55,696	13,144,256	15.362	6.179
44115.03	56,169	13,312,053	15.394	6.188
44488.09	56,644	13,481,272	15.427	6.197
44862.73	57,121	13,651,919	15.459	6.205
45238.93	57,600	13,824,000	15.491	6.214
45616.71	58,081	13,997,521	15.524	6.223
45996.06	58,564	14,172,488	15.556	6.231
46376.98	59,049	14,348,907	15.588	6.240
46759.47	59,536	14,526,784	15.620	6.248
47143.52	60,025	14,706,125	15.652	6.257
47529.16	60,516	14,886,936	15.684	6.265
47916.36	61,009	15,069,223	15.716	6.274
48305.13	61,504	15,252,992	15.748	6.282
48695.47	62,001	15,438,249	15.779	6.291

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Circumference	Circular Area	Square	Cube	Square Root	Cube Root
917.34	6943.19	83,264	24,897,088	17.088	6.631
924.49	67423.65	83,849	25,153,757	17.117	6.642
928.64	67883.68	86,486	25,112,181	17.145	6.649
929.71	68349.28	87,025	25,672,875	17.176	6.657
929.91	68813.45	87,516	25,934,436	17.205	6.661
933.10	69279.19	88,239	26,198,013	17.234	6.672
936.11	69743.50	88,804	26,664,792	17.263	6.679
939.31	70211.38	89,401	26,731,839	17.292	6.687
942.18	70681.83	90,000	27,000,000	17.320	6.691
945.12	71157.86	91,601	27,270,901	17.349	6.702
948.76	71631.45	91,234	27,543,608	17.378	6.709
951.90	72103.32	91,809	27,818,127	17.407	6.717
955.04	72583.36	92,416	28,094,464	17.436	6.724
958.19	73061.56	93,025	28,372,675	17.464	6.731
961.34	73541.54	93,636	28,652,616	17.493	6.739
964.47	74022.99	94,249	28,934,443	17.521	6.746
967.61	74506.01	94,864	29,218,112	17.549	6.753
970.75	74990.60	95,481	29,503,629	17.578	6.761
973.89	75476.76	96,100	29,791,000	17.606	6.768
977.03	75964.50	96,721	30,080,231	17.635	6.775
980.18	76453.80	97,344	30,371,328	17.663	6.782
983.32	76944.67	97,969	30,664,297	17.692	6.789
986.46	77437.12	98,595	30,959,111	17.721	6.797
989.60	77931.13	99,225	31,255,865	17.748	6.804
992.74	78426.72	99,855	31,554,495	17.776	6.811
995.88	78923.88	100,489	31,855,013	17.804	6.818
999.03	79422.50	101,124	32,157,632	17.832	6.826
1002.17	79922.90	101,751	32,461,159	17.860	6.833
1005.31	80424.77	102,400	32,768,000	17.888	6.839
1008.45	80928.21	103,041	33,076,101	17.916	6.847
1011.59	81433.22	103,684	33,385,218	17.944	6.854
1014.73	81939.80	104,329	33,695,267	17.972	6.861
1017.88	82447.96	104,976	34,012,224	18.000	6.868
1021.02	82957.68	105,625	34,328,125	18.028	6.875
1024.16	83468.98	106,276	34,645,976	18.056	6.882
1027.30	83981.81	106,929	34,965,783	18.083	6.889
1030.44	84496.28	107,581	35,287,552	18.111	6.895
1033.58	85012.28	108,241	35,611,280	18.138	6.903
1036.73	85529.86	108,900	35,937,000	18.165	6.910
1039.87	86049.01	109,561	36,264,691	18.193	6.917
1043.01	86569.73	110,224	36,594,368	18.221	6.924
1046.15	87092.02	110,889	36,925,037	18.248	6.931

No. or Diam.	Circum- ference	Circular Area	Square	Cube	Square Root
334	1049.20	87611.88	111,556	37,269,704	18.27
335	1052.43	88141.31	112,225	37,595,375	18.30
336	1055.67	88668.31	112,896	37,933,056	18.33
337	1058.72	89196.85	113,569	38,272,753	18.36
338	1061.86	89727.03	114,244	38,614,412	18.38
339	1065.00	90258.74	114,921	38,958,219	18.41
340	1068.14	90792.03	115,600	39,304,000	18.43
341	1071.28	91326.88	116,281	39,651,821	18.46
342	1074.42	91863.31	116,964	40,001,688	18.48
343	1077.57	92401.31	117,649	40,353,607	18.52
344	1080.71	92940.88	118,336	40,707,584	18.54
345	1083.85	93482.22	119,025	41,063,625	18.57
346	1086.99	94025.43	119,716	41,421,736	18.60
347	1090.15	94569.61	120,409	41,781,923	18.62
348	1093.27	95114.85	121,104	42,144,192	18.65
349	1096.42	95662.28	121,801	42,508,549	18.68
350	1099.56	96211.28	122,500	42,875,000	18.70
351	1102.70	96761.84	123,201	43,243,541	18.73
352	1105.84	97314.76	123,904	43,614,208	18.76
353	1108.98	97869.68	124,609	43,986,977	18.78
354	1112.12	98426.06	125,316	44,361,864	18.81
355	1115.26	98983.80	126,025	44,738,875	18.84
356	1118.41	99543.22	126,736	45,118,016	18.86
357	1121.57	100104.21	127,449	45,499,293	18.89
358	1124.73	100666.27	128,164	45,882,712	18.92
359	1127.88	101229.96	128,881	46,268,279	18.94
360	1131.07	101795.69	129,600	46,656,000	18.97
361	1134.21	102363.87	130,321	47,045,881	19.00
362	1137.26	102933.72	131,044	47,437,928	19.02
363	1140.40	103505.13	131,769	47,832,147	19.05
364	1143.54	104078.22	132,496	48,228,544	19.07
365	1146.68	104653.07	133,225	48,627,125	19.10
366	1149.82	105229.89	133,956	49,027,896	19.13
367	1152.95	105808.19	134,689	49,430,863	19.15
368	1156.11	106388.76	135,424	49,836,032	19.18
369	1159.27	106970.60	136,161	50,243,409	19.20
370	1162.39	107553.02	136,900	50,653,000	19.23
371	1165.53	108137.33	137,641	51,064,811	19.26
372	1168.67	108723.44	138,384	51,478,848	19.28
373	1171.81	109311.06	139,129	51,895,111	19.31
374	1174.96	109899.35	139,876	52,313,624	19.33
375	1178.10	110489.62	140,625	52,734,375	19.36

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N or Deg	Circu- ference	Circular Area	Square	Cube,	Square Root
82	257.61	5281.02	6,724	551,368	9.035
83	260.75	5410.61	6,889	571,787	9.110
84	263.89	5541.77	7,056	592,704	9.165
85	267.03	5674.50	7,225	614,125	9.219
86	270.18	5808.80	7,396	636,056	9.272
87	273.32	5944.68	7,569	658,603	9.325
88	276.47	6082.12	7,744	681,472	9.380
89	279.60	6221.14	7,921	704,969	9.432
90	282.74	6361.73	8,100	729,000	9.486
91	285.88	6503.88	8,281	753,571	9.539
92	289.03	6647.61	8,464	778,688	9.591
93	292.17	6792.91	8,649	804,357	9.645
94	295.31	6939.78	8,836	830,584	9.697
95	298.45	7088.22	9,025	857,375	9.749
96	301.59	7238.23	9,216	884,736	9.799
97	304.73	7389.81	9,409	912,673	9.849
98	307.88	7542.96	9,604	941,192	9.899
99	311.02	7697.69	9,801	970,299	9.949
100	314.16	7853.98	10,000	1,000,000	10.000
101	317.30	8011.85	10,201	1,030,301	10.049
102	320.44	8171.28	10,404	1,061,208	10.099
103	323.58	8332.29	10,609	1,092,727	10.148
104	326.73	8494.87	10,816	1,124,864	10.198
105	329.87	8659.01	11,025	1,157,625	10.246
106	333.01	8824.73	11,236	1,191,116	10.295
107	336.15	8992.02	11,449	1,225,043	10.344
108	339.29	9160.88	11,664	1,259,712	10.392
109	342.43	9331.32	11,881	1,295,029	10.440
110	345.57	9503.32	12,100	1,331,000	10.488
111	348.72	9676.89	12,321	1,367,631	10.536
112	351.86	9852.03	12,544	1,404,928	10.583
113	355.00	10,028.75	12,769	1,442,897	10.630
114	358.14	10,207.03	12,996	1,481,544	10.677
115	361.28	10,386.89	13,225	1,520,875	10.723
116	364.42	10,568.32	13,456	1,560,896	10.770
117	367.57	10,751.32	13,689	1,601,613	10.816
118	370.71	10,935.88	13,924	1,643,032	10.862
119	373.85	11,122.02	14,161	1,685,159	10.908
120	376.99	11,309.73	14,400	1,728,000	10.954
121	380.13	11,499.01	14,641	1,771,561	11.000
122	383.27	11,689.87	14,884	1,815,848	11.045
123	386.42	11,882.29	15,129	1,860,867	11.090

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THE MECHANICAL ENGINEER'S POCKET-BOOK.

MATHEMATICAL TABLES.

Introduction to the Tables.

TABLE 1.—*Circumferences and Areas of Circles, Squares, Square Roots, and Cube Roots of Numbers, from 1 to*

3 powers and roots of numbers may be calculated by use of logarithms; but this table will considerably economise calculation.

The columns of squares and cubes may be utilised inversely, reading in the first column the roots of numbers contained in the second and third columns.

The columns of square roots and cube roots, also, may be used for finding, in the first column, the squares and cubes of numbers containing decimals in those columns.

Further, the squares in the fourth column are the fourth powers of the square roots in the sixth column.

Again, any number in the first column may be conceived to consist of an integer and decimals; when the corresponding square or cube, with a decimal point suitably placed, will be the square or the cube of the assumed number. For example, we see that the number 186 represents 18·6, or 1·86, or ·186, whose square will contain two, or four, or six places of decimals respectively; and the cube will contain three, or six, or nine places of decimals respectively. Thus,—

Number.	Square.	Cube.
186	34,596	6,434,856
18·6	345·96	6,434·856
1·86	3·4596	6·434856
·186	·034596	·006434856

The number of places of decimals is fixed in each instance according to the common rule of twice the number of decimal places in the original number for a square, and three times the number in the original for a cube.

TABLE 2.—*Diameter, Circumference, and Area of Circles, advancing by Vulgar Fractions, from $\frac{1}{16}$ to 120.*

The diameters specifically represent lengths in inches and parts of inches. But they may represent values in any other units, as feet or yards.

TABLE 3.—*Reciprocals of Numbers, from 1 to 1000.*

The reciprocal of a number is the quotient obtained by dividing 1 by the given number.

The product of any number with its reciprocal is equal to 1. Hence a ready means of checking the accuracy of any reciprocal, which when multiplied by its number should give a quotient of 1.

The reciprocal of a vulgar fraction is equal to the quotient of the denominator by the numerator. Thus the reciprocal of $\frac{1}{2}$ is equal to $\left(\frac{2}{1} =\right) 2$. Or, the vulgar fraction may be reduced to a decimal form, and the decimal value divided into 1. Thus $\frac{1}{2} = .5$, and $1 \div .5 = 2$.

TABLE 4.—*Logarithms of Numbers, from 1 to 10,000.*

Logarithms are designed to abbreviate calculations involving multiplication and division of numbers, by the substitution of calculations by addition and subtraction respectively. Logarithms consist of integers and decimals, and they are given in Table 4 for numbers ranging from 1 to 10,000. The integers or indices, as they are called, are, except in the small preliminary tablet, omitted in the table, for the sake of brevity, but chiefly for the sake of clearness and simplicity. The decimal values of the logarithms are given to six places. The integer or index of each logarithm is less by 1 than the number of places in the integer of the number; and if the number contain only decimals, the index is equal to the number of cyphers next the decimal point, plus 1. The index in this case is negative, and is so distinguished by the sign minus, —, written over it. The adjustment of the integer of a logarithm to the composition of the given number is exemplified in the following series, in which the same number is repeated several

times, having the decimal point shifted regularly by one digit towards the left:—

5314	.	.	.	.	3.725422
531.4	.	.	.	.	2.725422
53.14	.	.	.	.	1.725422
5.314	.	.	.	.	0.725422
.5314	.	.	.	.	̄1.725422
.05314	.	.	.	.	2.725422
.005314	.	.	.	.	3.725422

To find the logarithm of a number. If the number contain only one or two digits, look for it in the columns marked N in the preliminary tablet, and find the logarithm next to it, or, look for the number in the body of the table, with one, or two, cyphers following it; and the decimal part of the logarithm stands next to the number, in the column headed 0. For example, the decimal part of the logarithm of 5, .698970, is in the column next to 500, in page 63 of the table; corresponding to the single digit in the integer, the integral figure of the logarithm is 0, and the complete logarithm is 0.698970. For 50, the logarithm is 1.698970; and for 500, the logarithm is 2.698970; but for .5, the logarithm is ̄1.698970.

In short, if the given number consist of one, two, or three digits, the decimal part of its logarithm is found in the column headed 0. If the number consist of four digits, look for the first, second, and third in the column N, and the fourth in the row of headings or footings at the top or the bottom of the table; and the logarithmic decimal is found opposite the number in the marginal column, and below or above the fourth. If the number consist of five or more digits, the logarithm for the first to the fourth digits being found as above, multiply the corresponding difference in the last column, D, by the remaining digits, and divide by 10 if there be only one digit more, by 100 if there be ten more, and so on. Add the quotient to the logarithm already obtained, to give the logarithm required. For example, to find the logarithm of 62.355. The decimal part of the logarithm of 6235 is .794836, and the corresponding difference ($70 \times 5 \div 10 =$) 35, is to be added, thus—

$$\begin{array}{r} 0.794836 \\ 35 \\ \hline \end{array}$$

0.794871 the completed logarithm.

Conversely, the number for a given logarithm is found by searching for the decimal part of the logarithm. If it be found exactly or within a few units of the right-hand digit,

note the first, second, and third digits of the required number in the column N, and the fourth digit at the top or the bottom, above or below the decimal ; and place the decimal point. If the logarithm differ materially from the nearest in the table, find the number for the next less logarithm in the table, to give the first, second, third, and fourth digits. To find the fifth and, if necessary, the sixth digit, subtract the tabulated logarithm from the given logarithm, add two cyphers, and divide by the difference found in column D in a line with the logarithm. Annex the quotient to the four digits already found, and place the decimal point. For example, to find the number represented by the logarithm 0.497151. The nearest less logarithm in the table is 0.497068, for the number 3141. Subtracting this logarithm from that, thus —

$$0.497151$$

$$0.497068$$

$$\hline 83$$

add two cyphers to the difference, making 8300, and divide by 138, the difference in column D. Then $8300 \div 138 = 60$, and annexing 60 to 3141, the number is 314160. Placing the decimal point, the completed number is 3.14160, or 3.1416.

To multiply two or more numbers together, add together their logarithms. The sum is the logarithm of the product. To divide one number by another, subtract the logarithm of this from the logarithm of that ; the number corresponding to the difference is the quotient.

To find any power of a given number, multiply the logarithm of the number by the exponent of the power. The product is the logarithm of the power.

To find any root of a given number, divide the logarithm of the number by the index of the root.

To find the reciprocal of a given number, subtract the decimal part of the logarithm of the number from 0.000000 ; add 1 to the index of the logarithm and change the sign of the index. For example, to find the reciprocal of 350 :—

$$0.000000$$

$$\log. 350 \quad . \quad . \quad 2.544068$$

$$\hline 3.455932 = \log. .002857.$$

Conversely, to find the reciprocal of the decimal .002857 :—

$$0.000000$$

$$\log. .002857 \quad . \quad 3.455932$$

$$\hline 2.544068 = \log. 350.$$

se two calculations afford examples of negative indices. First, the logarithm of 350 has the index 2, or $+2$, the of which is changed for subtraction, making -2 . In ting the digit 5, the first decimal, from 0, 1 is carried from the previous subtraction, making 6, which deducted 10 leaves 4. Carrying 1, -2 and -1 make -3 , which index of the remainder, $\bar{3}.455932$, the logarithm of 7.

the second calculation above, in deducting the first al, 4 augmented by 1 carried, or 5, from 10, there as 5, the first decimal in the remainder; and 1 is d to the index place. But, first, the sign of the index nged, and the index becomes $+3$; and from this the d 1 is deducted, leaving $+2$ the index of the remaining hm of 350.

Add together two negative indices, they are simply added the negative sign placed over the sum, thus $\bar{3} + \bar{2} = \bar{5}$. addition together of a positive index and a negative their difference is the sum, bearing the sign of the r additive; thus $3 + \bar{2} = 1$; or $2 + \bar{3} = \bar{1}$. For le:—

$$\log. 3442 = 3.536811$$

$$\log. .02801 = 2.447313$$

$$\log. 96.41 = 1.984124$$

subtract a negative index, change the sign and add. o subtract 2 from $\bar{3}$, there is $\bar{3} + 2 = \bar{1}$; but this may e simply thus $\bar{3} - \bar{2} = \bar{1}$. Again, 3 from 2 = $3 + 2 =$ subtract a positive index from a negative index. change itive sign to negative and add; thus, 3 from $\bar{5} = \bar{3} +$

find a root of a given number. Divide the logarithm number by the exponent of the root: the quotient is arithm of the root. If the index be negative, and is le without a remainder, the quotient of the index is e. If it be not so divisible, add to it so much in the e as will make it divisible, and divide it, to give the which is negative; prefix an equal quantity to the l part of the logarithm, and divide separately. The otients together make the logarithm of the root. For e, to find the square root of 1849:—

$$\log. 1849 = 3.266937$$

$$\text{divided by } 2 = 1.633469 = \log. 43.$$

To find the fourth root of .00578 :—

$$\log .00578 = \bar{9}.761928$$

$$\text{divide by 4, say } \bar{4} + 1.761928$$

$$\text{giving } 1.440482 = \log .2757.$$

It is, in ordinary practice, for the most part, unnecessary to note the indices of logarithms, as the numbers are mostly sufficiently indicated without the indices. Besides, in many cases, rough approximations suffice, particularly where numbers are expressed wholly or partly in decimals.

TABLE 5.—*Hyperbolic Logarithms of Numbers from 1.01 to 20.*

The table of hyperbolic logarithms is useful chiefly in calculations of the work of steam by expansion. The numbers range from 1.01 to 20. Hyperbolic, or Neperian, logarithms are calculated by multiplying the common logarithms of numbers, as given in Table 4, by the constant multiplier 2.302585.

TABLE 6.—*Sines and Cosines of Angles from 0° to 90°.*

The tabulated values are the proportional values when the length of the radius of the circle is taken as 1. When the actual length of the radius is given, the actual length of any sine or cosine is found by multiplying the tabular value by the length of the radius.

The table is arranged so that each value signifies the sine of an angle and the cosine of its complement for 90 degrees. The values are given for angles advancing by half a degree. The values for intermediate angles, sufficiently near exactness for most purposes, can be found by interpolation in simple proportion. By an inverse operation, the angle may be found for any given sine or cosine not given in the table.

TABLE 7.—*Tangents and Cotangents of Angles from 0° to 90°.*

The values are, like those of the sines and cosines, proportional values, the radius being taken as 1. The actual values of the tangents and cotangents are calculated by multiplying the actual length of the radius by the corresponding tabular value of the tangent or the cotangent.

Each tabular value is that of the tangent of an angle, and also that of the cotangent of the complementary angle. The values are given for angles advancing by half a degree; and values for intermediate angles may be found by interpolation. Inversely, the angle may be found for any given tangent or cotangent not found in the table.

TABLE 8.—*Lengths of Circular Arcs, from 1° to 180° .*

The lengths of circular arcs of which the magnitudes in degrees are given, are stated in proportion to the length of the radius, taken as 1. The actual length of the arc is found by multiplying the actual length of the radius by the tabular length corresponding to the number of degrees in the arc.

TABLE 9.—*Lengths of Circular Arcs, up to a Semicircle, when the Chord is given.*

In this table, the length of the arc is given proportionally to the length of the chord, which is taken as 1. The heights of the arcs in the table are the quotients arising by dividing the actual heights by the actual lengths of the chords, and are the ratios of the heights to the chords.

To use the table, therefore, divide the height of the arc by the length of the chord; find the quotient in the columns of heights in the table, and multiply the corresponding tabular length of the arc by the actual length of the chord. The product is the length of the arc.

TABLE 10.—*Areas of Circular Segments.*

The tabular areas of circular segments are in proportional superficial measure, corresponding to the length of the diameter, which is taken as 1. The tabular heights of the segments are the quotients of the heights divided by the diameters; the relative areas are given in the columns of areas.

To use the table, divide the actual height by the actual diameter, find the quotient in the columns of heights; and multiply the corresponding tabular area by the square of the actual length of the diameter. The product is the actual area.

TABLE 11.—*Lengths of Semi-Elliptic Arcs up to a Semi-Circle.*

This table has been calculated by means of Mr. Trautwine's formula. In the columns of heights are the ratios of the rise to the span or chord of an elliptic arc. To use the table, divide the given rise by the chord, and find the quotient in the columns of heights. Next to this quotient, in the adjoining column, is a multiplier, which when multiplied by the actual length of the span, gives the length of the arc.

	Circular Area	Square	Cube	Square Root.	Cube Root.
13	166196.25	211,600	97,336,000	21.447	7.719
17	166913.60	212,521	97,972,181	21.471	7.725
12	167638.53	213,444	98,611,128	21.494	7.731
56	168365.02	214,369	99,252,847	21.517	7.736
70	169095.08	215,296	99,897,345	21.541	7.742
84	169822.72	216,225	100,544,625	21.564	7.747
98	170553.92	217,156	101,194,696	21.587	7.753
12	171286.70	218,089	101,847,563	21.610	7.758
26	172021.05	219,024	102,503,232	21.633	7.764
41	172756.94	219,961	103,161,709	21.656	7.769
55	173494.45	220,900	103,823,000	21.679	7.775
69	174233.51	221,841	104,487,111	21.702	7.780
83	174974.14	222,784	105,154,048	21.725	7.786
97	175716.35	223,729	105,823,817	21.749	7.791
11	176460.12	224,676	106,496,424	21.771	7.797
26	177205.46	225,625	107,171,875	21.794	7.802
40	177952.37	226,576	107,850,176	21.817	7.808
54	178700.86	227,529	108,531,333	21.840	7.813
68	179450.91	228,484	109,215,372	21.863	7.819
82	180202.54	229,441	109,902,239	21.886	7.824
96	180955.74	230,400	110,592,000	21.909	7.830
11	181710.50	231,361	111,284,541	21.932	7.835
25	182466.84	232,324	111,980,168	21.954	7.840
39	183224.75	233,289	112,678,587	21.977	7.846
53	183984.23	234,256	113,379,404	22.000	7.851
67	184745.28	235,225	114,084,125	22.023	7.857
81	185507.90	236,196	114,791,256	22.047	7.862
96	186272.10	237,169	115,501,303	22.069	7.868
10	187037.86	238,144	116,214,272	22.091	7.873
24	187805.19	239,121	116,936,156	22.115	7.878
38	188574.10	240,100	117,649,000	22.136	7.884
52	189344.57	241,081	118,370,771	22.158	7.889
66	190116.61	242,064	119,095,488	22.181	7.894
80	190890.24	243,049	119,823,157	22.204	7.899
95	191665.48	244,036	120,553,784	22.226	7.905
109	192442.19	245,025	121,287,375	22.248	7.910
23	193220.51	246,016	122,023,936	22.271	7.915
37	194000.42	247,009	122,763,473	22.293	7.921
51	194781.89	248,004	123,505,992	22.316	7.926
65	195564.93	249,001	124,251,489	22.338	7.932
80	196349.54	250,000	125,000,000	22.361	7.937
94	197135.72	251,001	125,751,501	22.383	7.942

N or Dist.	Circum- ference	Circum- Area	Square.	Cube	Square Root	Cube Root
502	1 77 08	197923 48	252 084	126 786 008	22 465	7 947
503	1 80 22	198712 80	253 009	127 263 727	22 428	7 952
504	1 83 36	199503 70	254 036	128 024 864	22 419	7 958
505	1 86 50	200294 17	255 025	128 787 625	22 479	7 963
506	1 89 65	201090 20	256 036	129 544 216	22 494	7 969
507	1 92 79	201885 81	257 049	130 328 843	22 517	7 974
508	1 95 93	202682 99	258 064	131 096 512	22 539	7 979
509	1 99 07	203481 74	259 081	131 872 229	22 761	7 984
510	2 02 21	204282 06	260 100	132 651 000	22 583	7 989
511	2 05 35	205083 15	261 121	133 432 831	22 605	7 995
512	2 08 49	205887 42	262 144	134 217 728	22 627	8 000
513	2 11 63	206692 45	263 169	135 005 697	22 649	8 006
514	2 14 78	207499 35	264 196	135 796 744	22 671	8 011
515	2 17 92	208307 33	265 225	136 590 875	22 694	8 016
516	2 21 06	209116 97	266 256	137 388 096	22 716	8 021
517	2 24 20	209928 29	267 289	138 188 413	22 738	8 026
518	2 27 34	210741 18	268 324	138 991 832	22 760	8 031
519	2 30 48	211555 63	269 361	139 798 379	22 782	8 036
520	2 33 63	212371 36	270 400	140 608 000	22 803	8 041
521	2 36 77	213189 25	271 441	141 420 761	22 825	8 047
522	2 39 91	214008 45	272 484	142 236 648	22 847	8 052
523	2 43 05	214829 17	273 529	143 055 693	22 869	8 057
524	2 46 19	215651 49	274 576	143 877 824	22 891	8 062
525	2 49 33	216475 37	275 625	144 693 125	22 913	8 067
526	2 52 48	217300 82	276 676	145 511 576	22 935	8 072
527	2 55 62	218127 85	277 729	146 333 183	22 956	8 077
528	2 58 77	218956 44	278 784	147 157 962	22 978	8 082
529	3 01 91	219786 61	279 841	148 035 889	23 000	8 087
530	3 05 06	220 618 32	280 900	148 877 000	23 022	8 092
531	3 08 20	221 451 65	281 961	149 721 291	23 043	8 098
532	3 11 35	222 286 55	283 024	150 568 768	23 065	8 103
533	3 14 49	223 122 98	284 089	151 419 437	23 087	8 108
534	3 17 63	223 960 90	285 156	152 273 404	23 108	8 113
535	3 20 78	224 800 59	286 225	153 130 375	23 130	8 118
536	3 23 92	225 641 15	287 296	153 990 656	23 152	8 123
537	3 27 06	226 483 48	288 369	154 854 173	23 173	8 128
538	3 30 20	227 328 77	289 444	155 720 872	23 195	8 133
539	3 33 35	228 174 66	290 521	156 590 819	23 216	8 138
540	3 36 49	229 022 10	291 600	157 464 000	23 238	8 143
541	3 39 63	229 871 11	292 681	158 340 421	23 259	8 148
542	3 42 78	230 721 71	293 764	159 220 088	23 281	8 153
543	3 45 92	231 573 80	294 849	160 103 007	23 302	8 158

Dia- meter	Circum- ference.	Area	Dia- meter	Circum- ference.	Area.
63 $\frac{1}{2}$	198.706	3112.04	73 $\frac{1}{2}$	231.698	4271.83
63 $\frac{3}{4}$	199.491	3156.92	74	232.478	4306.84
63 $\frac{7}{8}$	200.277	3191.91	74 $\frac{1}{2}$	233.263	4329.50
64	201.062	3216.99	74 $\frac{3}{4}$	234.049	4359.16
64 $\frac{1}{4}$	201.847	3242.17	74 $\frac{7}{8}$	234.834	4388.41
64 $\frac{1}{2}$	202.633	3267.46	75	235.620	4417.86
64 $\frac{3}{4}$	203.418	3292.83	75 $\frac{1}{4}$	236.405	4447.87
65	204.204	3318.31	75 $\frac{1}{2}$	237.190	4477.97
65 $\frac{1}{4}$	204.989	3343.88	75 $\frac{3}{4}$	237.976	4506.67
65 $\frac{1}{2}$	205.774	3369.56	76	238.761	4536.46
65 $\frac{3}{4}$	206.560	3395.33	76 $\frac{1}{4}$	239.547	4566.36
66	207.345	3421.19	76 $\frac{1}{2}$	240.332	4596.37
66 $\frac{1}{4}$	208.131	3447.16	76 $\frac{3}{4}$	241.117	4626.44
66 $\frac{1}{2}$	208.916	3473.23	77	241.903	4656.63
66 $\frac{3}{4}$	209.701	3499.39	77 $\frac{1}{4}$	242.688	4686.92
67	210.487	3525.66	77 $\frac{1}{2}$	243.474	4717.30
67 $\frac{1}{4}$	211.272	3552.01	77 $\frac{3}{4}$	244.259	4747.79
67 $\frac{1}{2}$	212.058	3578.47	78	245.044	4778.86
67 $\frac{3}{4}$	212.843	3605.03	78 $\frac{1}{4}$	245.830	4809.05
68	213.628	3631.68	78 $\frac{1}{2}$	246.615	4839.83
68 $\frac{1}{4}$	214.414	3658.44	78 $\frac{3}{4}$	247.401	4870.70
68 $\frac{1}{2}$	215.199	3685.29	79	248.186	4901.68
68 $\frac{3}{4}$	215.985	3712.24	79 $\frac{1}{4}$	248.971	4932.75
69	216.770	3739.28	79 $\frac{1}{2}$	249.757	4963.92
69 $\frac{1}{4}$	217.555	3766.43	79 $\frac{3}{4}$	250.542	4995.19
69 $\frac{1}{2}$	218.341	3793.67	80	251.328	5026.55
69 $\frac{3}{4}$	219.126	3821.02	80 $\frac{1}{4}$	252.113	5058.00
70	219.912	3848.45	80 $\frac{1}{2}$	252.898	5089.58
70 $\frac{1}{4}$	220.697	3875.99	80 $\frac{3}{4}$	253.683	5121.22
70 $\frac{1}{2}$	221.482	3903.63	81	254.469	5153.00
70 $\frac{3}{4}$	222.268	3931.36	81 $\frac{1}{4}$	255.254	5184.84
71	223.053	3959.19	81 $\frac{1}{2}$	256.040	5216.82
71 $\frac{1}{4}$	223.839	3987.13	81 $\frac{3}{4}$	256.825	5248.84
71 $\frac{1}{2}$	224.624	4015.16	82	257.611	5281.02
71 $\frac{3}{4}$	225.409	4043.28	82 $\frac{1}{4}$	258.396	5313.28
72	226.195	4071.50	82 $\frac{1}{2}$	259.182	5345.62
72 $\frac{1}{4}$	226.980	4099.83	82 $\frac{3}{4}$	259.967	5378.04
72 $\frac{1}{2}$	227.766	4128.25	83	260.752	5410.61
72 $\frac{3}{4}$	228.551	4156.77	83 $\frac{1}{4}$	261.537	5443.24
73	229.336	4185.39	83 $\frac{1}{2}$	262.323	5476.00
73 $\frac{1}{4}$	230.122	4214.11	83 $\frac{3}{4}$	263.108	5508.84
74	230.907	4242.92	84	263.894	5541.77

No of Diam	Circum- ference	Circular Area	Square	Cube.	Square Root	Cube Root
586	1840.07 269702 59		343,396	201,230,056	24.207	8.368
587	1844.11 270028 86		344,569	202,262,003	24.228	8.373
588	1848.26 271146 70		345,744	203,297,472	24.249	8.378
589	1850.40 272471 12		346,921	204,336,449	24.269	8.382
590	1854.54 273397 10		348,100	205,379,800	24.289	8.387
591	1856.68 274324 00		349,281	206,425,71	24.310	8.392
592	1859.82 275253 78		350,464	207,474,688	24.331	8.397
593	1862.96 276184 48		351,649	208,527,857	24.351	8.401
594	1866.11 277116 75		352,836	209,584,584	24.372	8.406
595	1869.27 278050 59		354,025	210,644,875	24.393	8.411
596	1872.39 278985 99		355,216	211,708,736	24.413	8.415
597	1875.53 279922 07		356,409	212,776,173	24.433	8.420
598	1878.67 280861 53		357,604	213,847,192	24.454	8.425
599	1881.81 281801 05		358,801	214,921,709	24.474	8.429
600	1884.96 282743 34		360,000	216,000,000	24.495	8.434
601	1888.10 283686 60		361,201	217,081,801	24.515	8.439
602	1891.24 284631 44		362,404	218,167,208	24.536	8.444
603	1894.38 285577 84		363,609	219,256,227	24.556	8.448
604	1897.52 286525 82		364,816	220,348,864	24.576	8.453
	1900.66 287475 36		366,025	221,445,125	24.597	8.458
606	1903.80 288426 48		367,236	222,545,016	24.617	8.462
607	1906.95 289379 17		368,449	223,648,543	24.637	8.467
608	1910.09 290333 43		369,664	224,755,712	24.658	8.472
	1913.23 291289 26		370,881	225,866,529	24.678	8.476
610	1916.37 292246 66		372,100	226,981,000	24.698	8.481
611	1919.51 293205 63		373,321	228,099,131	24.718	8.485
612	1922.65 294166 17		374,544	229,220,928	24.738	8.490
613	1925.80 295128 28		375,769	230,346,397	24.758	8.495
614	1928.94 296091 97		376,996	231,475,544	24.779	8.499
615	1932.08 297057 22		378,225	232,608,375	24.799	8.504
616	1935.22 298024 55		379,456	233,744,896	24.819	8.509
617	1938.36 298992 44		380,689	234,885,113	24.839	8.513
618	1941.50 299962 41		381,924	236,029,032	24.859	8.518
	1944.64 300933 95		383,161	237,176,679	24.879	8.522
620	1947.79 301907 05		384,400	238,328,000	24.899	8.527
	1950.93 302881 73		385,641	239,483,061	24.919	8.532
622	1954.07 303857 98		386,884	240,641,848	24.939	8.536
623	1957.21 304835 80		388,129	241,804,369	24.959	8.541
624	1960.35 305815 20		389,376	242,971,624	24.980	8.545
625	1963.49 306797 16		390,625	244,143,625	25.000	8.549
626	1966.63 307778 59		391,876	245,314,376	25.019	8.554
627	1969.78 308762 79		393,129	246,491,883	25.040	8.558

No or Diam	Circum- ference	Circular Area	Square	Cube	Square Root	Cube Root
628	1972.92	309748.47	394,384	247,673,152	25.059	8.503
629	1974.00	310785.71	395,641	248,858,189	25.074	8.508
630	1975.20	311724.53	396,900	250,047,000	25.090	8.513
631	1982.34	312714.92	398,161	251,239,591	25.116	8.517
632	1985.49	313706.88	399,424	252,435,068	25.139	8.522
633	1988.63	314700.40	400,689	253,636,137	25.160	8.526
634	1991.77	315695.50	401,956	254,840,104	25.179	8.531
635	1994.91	316692.17	403,225	256,047,875	25.199	8.535
636	1998.05	317690.42	404,496	257,259,456	25.219	8.539
637	2001.19	318690.23	405,769	258,474,853	25.239	8.544
638	2004.34	319691.61	407,044	259,694,072	25.259	8.549
639	2007.48	320694.56	408,321	260,917,119	25.278	8.553
640	2010.62	321699.09	409,600	262,144,000	25.298	8.558
641	2013.76	322705.18	410,881	263,374,721	25.318	8.562
642	2016.90	323712.85	412,164	264,609,288	25.338	8.567
643	2020.04	324722.00	413,449	265,847,707	25.357	8.571
644	2023.19	325732.89	414,736	267,089,984	25.377	8.576
645	2026.33	326745.27	416,025	268,336,125	25.397	8.580
646	2029.47	327759.22	417,316	269,586,136	25.416	8.585
647	2032.61	328774.74	418,609	270,840,023	25.436	8.589
648	2035.75	329791.83	419,904	272,097,792	25.456	8.593
649	2038.89	330810.49	421,201	273,359,449	25.475	8.598
650	2042.04	331830.72	422,500	274,625,000	25.495	8.602
651	2045.18	332852.53	423,801	275,894,451	25.515	8.607
652	2048.32	333875.90	425,104	277,167,808	25.534	8.611
653	2051.46	334900.85	426,409	278,445,077	25.554	8.616
654	2054.60	335927.36	427,716	279,726,264	25.573	8.620
655	2057.74	336955.45	429,024	281,011,375	25.593	8.624
656	2060.88	337985.10	430,336	282,300,416	25.612	8.629
657	2064.03	339016.33	431,649	283,593,393	25.632	8.633
658	2067.17	340049.13	432,964	284,890,312	25.651	8.638
659	2070.31	341083.50	434,281	286,191,179	25.671	8.642
660	2073.45	342119.44	435,600	287,496,000	25.690	8.646
661	2076.59	343156.95	436,921	288,804,781	25.710	8.651
662	2079.73	344196.03	438,244	290,117,528	25.729	8.655
663	2082.88	345236.69	439,569	291,434,247	25.749	8.659
664	2086.02	346278.91	440,896	292,754,944	25.768	8.664
665	2089.16	347322.70	442,225	294,079,625	25.787	8.668
666	2092.30	348368.07	443,556	295,408,296	25.807	8.673
667	2095.44	349415.00	444,889	296,740,963	25.826	8.677
668	2098.58	350463.51	446,224	298,077,632	25.846	8.682
669	2101.73	351513.59	447,561	299,418,309	25.865	8.686

No. or Diam	Circum- ference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
670	2104.84	312565.24	448,960	300,753,000	25.884	8.750
671	2104.01	313118.43	450,241	302,111,711	25.904	8.755
672	2111.13	314673.24	451,584	303,434,448	25.923	8.759
673	2114.23	315729.60	452,929	304,821,217	25.942	8.763
674	2117.43	316787.51	454,276	306,182,024	25.961	8.768
675	2120.58	317847.04	455,625	307,546,875	25.981	8.772
676	2123.72	318908.11	456,971	308,915,776	26.000	8.776
677	2126.84	319970.75	458,329	310,288,783	26.019	8.781
678	2130.00	321034.97	459,684	311,665,752	26.038	8.785
679	2133.14	322100.75	461,041	313,046,839	26.058	8.789
680	2136.28	323168.11	462,400	314,442,000	26.077	8.794
681	2139.42	324237.94	463,761	315,841,241	26.096	8.798
682	2142.57	325307.54	465,124	317,244,568	26.115	8.802
683	2145.71	326379.60	466,489	318,641,987	26.134	8.807
684	2148.86	327453.24	467,856	320,043,504	26.153	8.811
685	2151.99	328528.45	469,225	321,449,125	26.172	8.815
686	2155.13	329605.23	470,596	322,858,856	26.192	8.819
687	2158.27	330683.50	471,969	324,272,703	26.211	8.824
688	2161.41	331763.51	473,344	325,690,672	26.229	8.828
689	2164.55	332845.00	474,721	327,112,769	26.248	8.832
690	2167.70	333928.07	476,100	328,539,000	26.268	8.836
691	2170.84	335012.70	477,481	329,969,371	26.287	8.841
692	2173.98	336098.91	478,864	331,393,888	26.306	8.845
693	2177.12	337186.75	480,249	332,812,557	26.325	8.849
694	2180.27	338276.03	481,636	334,235,384	26.344	8.853
695	2183.41	339366.95	483,025	335,662,375	26.363	8.858
696	2186.55	340459.44	484,416	337,093,536	26.382	8.862
697	2189.70	341553.50	485,809	338,528,873	26.401	8.866
698	2192.83	342649.15	487,204	340,058,392	26.419	8.870
699	2195.97	343746.33	488,601	341,532,099	26.439	8.875
700	2199.12	344845.10	490,000	343,060,000	26.457	8.879
701	2202.26	345945.44	491,401	344,472,101	26.476	8.883
702	2205.40	347047.35	492,804	345,918,388	26.495	8.887
703	2208.54	348150.84	494,209	347,428,927	26.514	8.892
704	2211.68	349255.90	495,615	348,913,544	26.533	8.896
705	2214.82	350362.51	497,023	350,402,525	26.552	8.900
706	2217.97	351470.72	498,433	351,895,811	26.571	8.904
707	2221.11	352580.49	499,845	353,393,243	26.589	8.908
708	2224.25	353691.83	501,254	354,894,912	26.608	8.913
709	2227.39	354804.74	502,661	356,400,829	26.627	8.917
710	2230.53	355919.21	504,070	357,911,000	26.644	8.921
711	2233.67	357035.27	505,481	359,425,431	26.664	8.925

Rad. No.	Circular Area.	Square	Cube	Square Root	Cube Root
3-61	3981.2289	571,944	340,944.128	26.583	8.929
3-62	3992.7208	508,340	362,467.097	26.709	8.934
3-63	4004.21284	509,795	363,944.344	26.721	8.938
3-64	4015.7118	511,227	365,527.871	26.731	8.942
3-65	4027.21908	512,635	367,061.494	26.738	8.946
3-66	4038.73645	514,080	368,601.813	26.777	8.950
3-67	4049.26162	515,524	370,146.232	26.795	8.954
3-68	4060.2022	516,961	371,694.959	26.814	8.959
3-69	4071.5041	518,400	373,248.000	26.833	8.963
3-70	4082.82717	519,841	374,805.344	26.851	8.967
3-71	4094.17555	521,284	376,367.048	26.870	8.971
3-72	4105.5040	522,729	377,933.067	26.889	8.975
3-73	4116.8187	524,176	379,503.424	26.907	8.979
3-74	4128.2491	525,625	381,078.125	26.926	8.983
3-75	4139.6452	527,075	382,657.175	26.944	8.988
3-76	4151.0571	528,526	384,240.588	26.963	8.992
3-77	4162.4846	529,984	385,828.352	26.981	8.996
3-78	4173.9279	531,441	387,420.189	27.000	9.000
3-79	4185.3868	532,900	389,017.000	27.018	9.004
3-80	4196.8615	534,361	390,617.891	27.037	9.008
3-81	4208.3519	535,824	392,223.168	27.055	9.012
3-82	4219.8579	537,289	393,832.837	27.073	9.016
3-83	4231.3797	538,756	395,446.904	27.092	9.020
3-84	4242.9172	540,225	397,065.375	27.111	9.023
3-85	4254.4704	541,696	398,688.256	27.129	9.029
3-86	4266.0393	543,169	400,315.533	27.148	9.033
3-87	4277.6240	544,644	401,947.272	27.166	9.037
3-88	4289.2243	546,121	403,583.419	27.184	9.041
3-89	4300.8403	547,600	405,224.000	27.203	9.045
3-90	4312.4721	549,081	406,869.031	27.221	9.049
3-91	4324.1195	550,564	408,518.488	27.238	9.053
3-92	4335.7827	552,049	410,172.467	27.258	9.057
3-93	4347.4611	553,535	411,830.784	27.276	9.061
3-94	4359.1547	555,025	413,493.625	27.295	9.065
3-95	4370.8634	556,516	415,150.934	27.313	9.069
3-96	4382.5874	558,009	416,812.723	27.331	9.073
3-97	4394.3261	559,504	418,478.992	27.349	9.077
3-98	4406.0796	561,001	420,149.749	27.368	9.081
3-99	4417.8477	562,500	421,825.000	27.386	9.086
3-100	4429.6303	564,001	423,504.751	27.404	9.090
3-101	4441.4278	565,504	425,188.900	27.423	9.094
3-102	4453.2403	567,009	426,877.777	27.441	9.098

No.	Reciprocal	No.	Reciprocal	No.	Reciprocal	No.	Reciprocal
433	.002299	475	.002105	517	.001934	559	.001789
434	.002304	476	.002101	518	.001931	560	.001786
435	.002309	477	.002097	519	.001927	561	.001783
436	.002314	478	.002092	520	.001923	562	.001779
437	.002318	479	.002088	521	.001919	563	.001776
438	.002323	480	.002085	522	.001916	564	.001773
439	.002328	481	.002081	523	.001912	565	.001770
440	.002333	482	.002077	524	.001908	566	.001767
441	.002338	483	.002073	525	.001905	567	.001764
442	.002342	484	.002069	526	.001901	568	.001761
443	.002347	485	.002065	527	.001898	569	.001757
444	.002352	486	.002062	528	.001894	570	.001754
445	.002357	487	.002058	529	.001890	571	.001751
446	.002362	488	.002054	530	.001887	572	.001748
447	.002367	489	.002051	531	.001883	573	.001745
448	.002372	490	.002047	532	.001880	574	.001742
449	.002377	491	.002043	533	.001876	575	.001739
450	.002382	492	.002039	534	.001873	576	.001736
451	.002387	493	.002035	535	.001869	577	.001733
452	.002392	494	.002031	536	.001866	578	.001730
453	.002397	495	.002027	537	.001862	579	.001727
454	.002402	496	.002023	538	.001859	580	.001724
455	.002407	497	.002019	539	.001855	581	.001721
456	.002412	498	.002015	540	.001852	582	.001718
457	.002417	499	.002011	541	.001848	583	.001715
458	.002422	500	.002007	542	.001845	584	.001712
459	.002427	501	.001999	543	.001842	585	.001709
460	.002432	502	.001995	544	.001838	586	.001706
461	.002437	503	.001991	545	.001835	587	.001703
462	.002442	504	.001987	546	.001832	588	.001701
463	.002447	505	.001983	547	.001828	589	.001698
464	.002452	506	.001979	548	.001825	590	.001695
465	.002457	507	.001975	549	.001821	591	.001692
466	.002462	508	.001971	550	.001818	592	.001689
467	.002467	509	.001967	551	.001815	593	.001686
468	.002472	510	.001963	552	.001812	594	.001684
469	.002477	511	.001959	553	.001808	595	.001681
470	.002482	512	.001955	554	.001805	596	.001678
471	.002487	513	.001951	555	.001802	597	.001675
472	.002492	514	.001947	556	.001799	598	.001672
473	.002497	515	.001943	557	.001795	599	.001669
474	.002502	516	.001939	558	.001792	600	.001667

No. or Diam.	Circum- ference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
334	1049.29	87615.88	111,556	37,259,704	18.276	6.938
335	1052.43	88141.31	112,225	37,595,375	18.303	6.945
336	1055.57	88668.31	112,896	37,933,056	18.330	6.952
337	1058.72	89196.88	113,569	38,272,753	18.357	6.959
338	1061.86	89727.03	114,244	38,614,472	18.385	6.966
339	1065.00	90258.74	114,921	38,958,219	18.412	6.973
340	1068.14	90792.03	115,600	39,304,000	18.439	6.979
341	1071.28	91326.88	116,281	39,651,821	18.466	6.986
342	1074.42	91863.31	116,964	40,001,688	18.493	6.993
343	1077.57	92401.31	117,649	40,353,607	18.520	7.000
344	1080.71	92940.88	118,336	40,707,584	18.547	7.007
345	1083.85	93482.02	119,025	41,063,625	18.574	7.014
346	1086.99	94024.73	119,716	41,421,736	18.601	7.020
347	1090.13	94569.01	120,409	41,781,923	18.628	7.027
348	1093.27	95114.86	121,104	42,144,192	18.655	7.034
349	1096.42	95662.28	121,801	42,508,549	18.681	7.040
350	1099.56	96211.28	122,500	42,875,000	18.708	7.047
351	1102.70	96761.84	123,201	43,243,551	18.735	7.054
352	1105.84	97314.76	123,904	43,614,208	18.762	7.061
353	1108.98	97867.68	124,609	43,986,977	18.788	7.067
354	1112.12	98422.96	125,316	44,361,864	18.815	7.074
355	1115.26	98979.80	126,025	44,738,875	18.842	7.081
356	1118.41	99538.22	126,736	45,118,016	18.868	7.087
357	1121.55	100098.21	127,449	45,499,293	18.894	7.094
358	1124.69	100659.27	128,164	45,882,712	18.921	7.101
359	1127.83	101222.90	128,881	46,268,279	18.947	7.107
360	1130.97	101787.60	129,600	46,656,000	18.974	7.114
361	1134.11	102353.87	130,321	47,045,881	19.000	7.120
362	1137.26	102921.72	131,044	47,437,928	19.026	7.127
363	1140.40	103491.13	131,769	47,832,147	19.052	7.133
364	1143.54	104062.12	132,496	48,228,544	19.079	7.140
365	1146.68	104634.67	133,225	48,627,125	19.105	7.146
366	1149.82	105208.80	133,956	49,027,896	19.131	7.153
367	1152.96	105784.49	134,689	49,430,863	19.157	7.159
368	1156.11	106361.76	135,424	49,836,032	19.183	7.166
369	1159.25	106940.60	136,161	50,243,409	19.209	7.172
370	1162.39	107521.01	136,900	50,653,000	19.235	7.179
371	1165.53	108102.99	137,641	51,064,811	19.261	7.185
372	1168.67	108686.54	138,384	51,478,848	19.287	7.192
373	1171.81	109271.66	139,129	51,895,117	19.313	7.198
374	1174.96	109858.35	139,876	52,313,624	19.339	7.205
375	1178.10	110446.62	140,625	52,734,375	19.365	7.211

No. Page	Common Logarithm	Circular Area	Square	Cube	Square Root
838	2.6326475154115		602,344	588,480,472	28.94
839	2.6358055285836		604,021	590,589,719	28.96
840	2.6389577115691		605,696	592,710,000	28.98
841	2.64210877519720		607,381	594,825,321	29.00
842	2.6452527681102		609,064	596,944,088	29.01
843	2.6483977811242		610,749	599,077,107	29.03
844	2.6515457941539		612,436	601,211,584	29.05
845	2.6546875070952		614,125	603,351,125	29.06
846	2.6578271221235		615,816	605,495,736	29.08
847	2.6609656311571		617,509	607,645,323	29.10
848	2.66410304178295		619,204	609,800,192	29.12
849	2.6672393511778		620,901	611,960,049	29.13
850	2.67037456717017		622,599	614,125,000	29.15
851	2.6735085878514		624,299	616,295,531	29.17
852	2.6766414712367		625,994	618,470,208	29.18
853	2.67977325110277		627,690	620,650,477	29.20
854	2.6829027280947		629,386	622,835,804	29.22
855	2.6860307711569		631,082	625,025,375	29.24
856	2.68915777548971		632,773	627,222,16	29.25
857	2.69228377834190		634,469	629,422,793	29.27
858	2.69540877818185		636,162	631,628,512	29.29
859	2.69853277707338		637,851	633,839,779	29.30
860	2.70165578088018		639,541	636,055,000	29.32
861	2.70477778223215		641,231	638,277,381	29.34
862	2.70789778358539		642,921	640,503,928	29.36
863	2.7110167849491		644,610	642,735,647	29.37
864	2.71413478632059		646,300	644,972,514	29.39
865	2.71725178769154		647,990	647,214,627	29.41
866	2.720367789061407		649,680	649,461,801	29.42
867	2.72348279043115		651,370	651,714,804	29.44
868	2.72659679179783		653,060	653,972,542	29.46
869	2.72970979316200		654,750	656,234,909	29.47
870	2.73282179452787		656,440	658,503,000	29.49
871	2.73593279589325		658,130	660,776,311	29.51
872	2.73904279726012		659,820	663,054,848	29.52
873	2.74215179862712		661,510	665,338,017	29.54
874	2.74525979999481		663,200	667,627,024	29.56
875	2.74836679136247		664,890	669,921,875	29.58
876	2.75147279272970		666,580	672,221,376	29.59
877	2.75457779409670		668,270	674,526,133	29.61
878	2.75768179546388		669,960	676,836,152	29.63
879	2.76078479683022		671,650	679,151,439	29.64

No. or Dim.	Circum- ference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
418	1313.19	137227.01	174,794	73,084,032	20.445	7.477
419	1314.33	137885.79	175,861	73,500,059	20.460	7.480
420	1315.47	138544.24	176,400	74,000,000	20.494	7.480
421	1316.61	139204.70	177,341	74,510,461	20.518	7.486
422	1317.75	139866.85	178,084	75,151,448	20.543	7.501
423	1318.89	140530.75	178,929	75,680,967	20.567	7.507
424	1319.03	141195.74	179,776	76,225,024	20.591	7.513
425	1320.18	141862.54	180,625	76,765,625	20.615	7.516
426	1321.32	142530.92	181,476	77,300,776	20.639	7.524
427	1322.46	143200.86	182,329	77,854,489	20.664	7.530
428	1323.60	143872.38	183,184	78,402,752	20.688	7.538
429	1324.74	144545.46	184,041	78,953,889	20.712	7.542
430	1325.88	145220.12	184,900	79,507,000	20.736	7.548
431	1327.02	145896.25	185,761	80,062,991	20.760	7.554
432	1328.17	146574.15	186,624	80,621,568	20.785	7.559
433	1329.31	147253.32	187,489	81,182,737	20.809	7.565
434	1330.45	147934.46	188,356	81,746,504	20.833	7.571
435	1331.59	148616.97	189,225	82,312,875	20.857	7.577
436	1332.73	149301.05	190,096	82,881,856	20.881	7.583
437	1333.88	149986.70	190,969	83,453,453	20.904	7.588
438	1335.02	150673.95	191,844	84,027,672	20.928	7.594
439	1336.16	151362.72	192,721	84,604,519	20.952	7.600
440	1337.30	152053.08	193,600	85,184,000	20.976	7.606
441	1338.44	152745.02	194,481	85,766,121	21.000	7.612
442	1339.58	153438.53	195,364	86,350,888	21.024	7.617
443	1340.73	154133.60	196,249	86,938,207	21.047	7.623
444	1341.87	154830.25	197,136	87,528,284	21.071	7.629
445	1343.01	155528.47	198,025	88,121,125	21.095	7.635
446	1344.15	156228.26	198,916	88,716,856	21.119	7.640
447	1345.29	156929.62	199,809	89,314,623	21.142	7.646
448	1346.43	157632.55	200,704	89,915,392	21.166	7.652
449	1347.57	158337.06	201,601	90,518,849	21.189	7.657
450	1348.72	159043.14	202,500	91,125,000	21.213	7.663
451	1349.86	159750.77	203,401	91,733,851	21.237	7.669
452	1351.00	160459.94	204,304	92,345,408	21.260	7.674
453	1352.14	161170.77	205,209	92,959,677	21.284	7.680
454	1353.28	161883.14	206,106	93,576,664	21.307	7.686
455	1354.42	162597.06	207,025	94,196,375	21.331	7.691
456	1355.57	163312.55	207,936	94,818,816	21.354	7.697
457	1356.71	164029.62	208,849	95,443,993	21.377	7.703
458	1357.85	164748.27	209,764	96,071,912	21.401	7.708
459	1359.00	165468.47	210,681	96,702,579	21.424	7.714

N.	0	1	2	3	4	5	6	7	8	9	N.
0	00000	00000	33010	47712	60260	69897	77815	84508	90309	95123	0
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2	30103	32219	34223	36128	38021	39794	41493	43136	44718	46239	2
3	47712	49136	50510	51811	53149	54408	55603	56820	57978	59105	3
4	60260	61578	62824	64018	65158	66243	67275	68258	69191	70106	4
5	69897	70750	71603	72426	73289	74083	74818	75585	76342	77052	5
6	77815	78590	79292	79941	80618	81293	81954	82605	83250	83849	6
7	84508	85125	85733	86323	86922	87501	88081	88649	89205	89727	7
8	90309	90848	91381	91908	92429	92941	93448	93951	94448	94939	8
9	95423	95901	96378	96843	97312	97774	98227	98672	99122	99563	9
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N.	0	1	2	3	4	5	6	7	8	9	N.
100	99800	99843	99868	99881	99894	99906	99918	99929	99941	99951	100
101	99962	99974	99981	99988	99994	99999	100000	100001	100002	100003	101
102	100004	100005	100006	100007	100008	100009	100010	100011	100012	100013	102
103	100014	100015	100016	100017	100018	100019	100020	100021	100022	100023	103
104	100024	100025	100026	100027	100028	100029	100030	100031	100032	100033	104
105	100034	100035	100036	100037	100038	100039	100040	100041	100042	100043	105
106	100044	100045	100046	100047	100048	100049	100050	100051	100052	100053	106
107	100054	100055	100056	100057	100058	100059	100060	100061	100062	100063	107
108	100064	100065	100066	100067	100068	100069	100070	100071	100072	100073	108
109	100074	100075	100076	100077	100078	100079	100080	100081	100082	100083	109
110	100084	100085	100086	100087	100088	100089	100090	100091	100092	100093	110
N.	0	1	2	3	4	5	6	7	8	9	N.

• See Introduction, ante, p. 2.

Circumference	Circular Area	Square	Cube	Square Root	Cube Root
2764.60	608212.34	774,400	681,472,000	27.665	9.588
2767.74	609593.42	776,161	683,797,841	27.682	9.586
2770.89	610980.08	777,924	686,128,968	27.698	9.590
2774.03	612366.31	779,689	688,465,387	27.715	9.594
2777.17	613754.11	781,456	690,807,164	27.732	9.597
2780.31	615143.48	783,225	693,151,125	27.749	9.601
2783.45	616534.42	784,996	695,506,456	27.766	9.604
2786.59	617926.93	786,769	697,864,103	27.782	9.608
2789.73	619321.01	788,544	700,227,072	27.799	9.612
2792.88	620716.66	790,321	702,595,369	27.816	9.615
2796.02	622113.89	792,100	704,969,000	27.833	9.619
2799.16	623512.68	793,881	707,347,971	27.850	9.623
2802.30	624913.04	795,664	709,732,288	27.866	9.626
2805.44	626314.98	797,449	712,121,957	27.883	9.630
2808.58	627718.49	799,236	714,516,984	27.900	9.633
2811.73	629123.56	801,025	716,917,375	27.916	9.637
2814.87	630530.21	802,816	719,323,136	27.933	9.640
2818.01	631938.43	804,609	721,734,273	27.950	9.644
2821.15	633348.22	806,404	724,150,792	27.967	9.648
2824.29	634759.58	808,201	726,572,699	27.983	9.651
2827.43	636172.51	810,000	729,000,000	30.000	9.655
2830.58	637587.01	811,804	731,432,701	30.017	9.658
2833.72	639003.09	813,604	733,874,808	30.033	9.662
2836.86	640420.73	815,409	736,314,327	30.050	9.666
2840.00	641839.95	817,216	738,763,264	30.066	9.669
2843.14	643260.73	819,025	741,217,625	30.083	9.673
2846.28	644683.09	820,836	743,677,416	30.100	9.676
2849.43	646107.01	822,649	746,142,643	30.116	9.680
2852.57	647532.51	824,464	748,613,312	30.133	9.683
2855.71	648959.58	826,281	751,089,429	30.150	9.687
2858.85	650388.21	828,100	753,571,000	30.163	9.690
2861.99	651818.43	829,921	756,058,031	30.183	9.694
2865.13	653250.21	831,744	758,550,528	30.199	9.698
2868.27	654683.56	833,569	761,048,497	30.216	9.701
2871.42	656118.48	835,396	763,551,944	30.232	9.705
2874.56	657554.98	837,225	766,060,875	30.249	9.708
2877.70	658993.04	839,056	768,575,296	30.265	9.712
2880.84	660432.68	840,889	771,095,213	30.282	9.715
2883.98	661873.88	842,724	773,620,632	30.298	9.718
2887.12	663316.60	844,561	776,151,659	30.315	9.722
2890.27	664761.01	846,400	778,688,000	30.331	9.726
2893.41	666207.92	848,241	781,229,961	30.348	9.729

No. or Index.	Circular Arcs.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
922	2896.55.667674.41		860.084	783,777,448	30.364	9.75
923	2899.69.669403.47		851.929	786,430,467	30.381	9.75
924	2902.83.670134.50		853.776	788,882,624	30.397	9.75
925	2905.97.671006.36		855.621	791,153,125	30.413	9.75
926	2909.12.673466.38		857.476	794,022,116	30.430	9.75
927	2912.26.671017.42		859.329	796,597,983	30.447	9.75
928	2915.41.676372.35		861.184	799,178,752	30.463	9.75
929	2918.54.677830.82		863.041	801.765,899	30.479	9.75
930	2921.68.671236.87		864.900	804,357,600	30.496	9.76
931	2924.82.680122.5		866.761	806,954,491	30.512	9.76
932	2927.96.682117.09		868.624	809,557,668	30.528	9.76
933	2931.11.683689.46		870.489	812,166,237	30.545	9.77
934	2934.25.681118.9		872.356	814,780,594	30.561	9.77
935	2937.39.8661171		874.225	817,400,375	30.578	9.77
936	2940.53.688684.15		876.096	820.025,856	30.594	9.76
937	2943.67.681125.25		877.969	822,656,963	30.611	9.78
938	2946.81.681125.86		879.844	825,293,672	30.627	9.78
939	2949.96.682525.5		881.721	827,936,019	30.643	9.79
940	2953.10.683378.82		883.600	830,584,000	30.659	9.79
941	2956.24.684755.15		885.481	833,237,621	30.676	9.79
942	2959.38.686034.06		887.364	835,896,888	30.692	9.80
943	2962.52.688114.53		889.249	838,561,897	30.708	9.80
944	2965.66.688955.58		891.136	841,232,384	30.724	9.81
945	2968.81.691382.28		893.025	843,908,625	30.741	9.81
946	2971.95.702835.38		894.916	846,590,596	30.757	9.81
947	2975.09.704352.14		896.809	849,278,129	30.773	9.82
948	2978.23.705844.47		898.704	851,971,399	30.790	9.82
949	2981.37.707333.37		900.601	854,670,349	30.806	9.82
950	2984.51.708821.84		902.500	857,375,600	30.822	9.83
951	2987.65.710314.88		904.401	860,087,351	30.838	9.83
952	2990.78.711809.58		906.304	862,801,448	30.854	9.83
953	2993.92.713305.68		908.209	865,523,177	30.871	9.84
954	2997.08.714803.48		910.116	868,250,664	30.887	9.84
955	3000.22.716302.76		912.025	870,983,875	30.903	9.84
956	3003.36.717803.63		913.936	873,722,816	30.919	9.85
957	3006.50.719306.12		915.849	876,467,493	30.935	9.85
958	3009.64.720810.40		917.761	879,217,912	30.951	9.85
959	3012.79.722315.77		919.681	881,974,079	30.968	9.86
960	3015.93.723822.95		921.600	884,736,000	30.984	9.86
961	3019.07.725331.70		923.521	887,503,681	31.000	9.86
962	3022.21.726842.52		925.444	890,277,128	31.016	9.87
963	3025.35.728353.91		927.369	893,056,347	31.032	9.87

N	0	1	2	3	4	5	6	7	8	9	n.
181	206826	207096	207366	207634	207904	208173	208441	208710	208979	209247	269
182	209515	209783	210051	210319	210586	210853	211121	211388	211654	211921	267
183	212188	212454	212720	212986	213252	213518	213783	214049	214314	214579	266
184	214844	215109	215373	215638	215902	216166	216430	216694	216957	217221	264
185	217484	217747	218010	218273	218536	218798	219060	219323	219585	219846	262
186	220108	220370	220631	220892	221153	221414	221675	221936	222196	222456	260
187	222716	222976	223236	223496	223755	224015	224274	224533	224792	225051	259
188	225302	225568	225826	226084	226342	226600	226858	227117	227375	227630	257
189	227887	228144	228400	228657	228913	229170	229426	229682	229938	230193	256
190	230449	230704	230960	231215	231470	231724	231979	232234	232488	232742	254
191	232006	232250	232504	232757	233011	233264	233517	233770	234023	234276	253
192	235528	235781	236033	236285	236537	236789	237041	237292	237544	237795	251
193	238046	238297	238548	238799	239049	239299	239550	239800	240050	240300	250
194	240549	240799	241048	241297	241546	241795	242044	242293	242541	242790	249
195	243038	243286	243534	243782	244030	244277	244525	244772	245019	245266	247
196	245713	245959	246206	246452	246699	246945	247191	247437	247682	247928	246
197	247973	248219	248464	248709	248954	249198	249443	249687	249932	250176	244
198	250420	250664	250908	251151	251395	251638	251881	252125	252368	252610	243
199	252853	253096	253338	253580	253822	254064	254306	254548	254790	255031	242
200	255273	255514	255755	255996	256237	256477	256718	256958	257198	257439	240
201	257679	257918	258158	258398	258637	258877	259116	259355	259594	259833	239
202	260071	260310	260548	260787	261025	261263	261501	261739	261976	262214	238
203	262451	262688	262925	263162	263399	263636	263873	264109	264346	264582	236
204	264818	265054	265290	265526	265761	265996	266232	266467	266702	266937	235
205	267173	267406	267641	267875	268110	268344	268578	268812	269046	269279	234

TABLE 2.—CIRCLES: DIAMETER (FROM
CIRCUMFERENCE, AND AREA.*

Dia- meter	Circum- ference.	Area	Dia- meter	Circum- ference.
$\frac{1}{16}$	1963	00307	$2\frac{9}{16}$	8.0503
$\frac{1}{8}$	3927	01227	$2\frac{1}{2}$	8.2467
$\frac{3}{16}$	5890	02761	$2\frac{11}{16}$	8.4430
$\frac{1}{4}$	7854	04909	$2\frac{1}{2}$	8.6394
$\frac{5}{16}$	9817	07679	$2\frac{13}{16}$	8.8357
$\frac{3}{8}$	11781	1104	$2\frac{3}{4}$	9.0321
$\frac{7}{16}$	13744	1503	$2\frac{15}{16}$	9.2284
$\frac{1}{2}$	15708	1963	3	9.4248
$\frac{9}{16}$	17771	2485	$3\frac{1}{16}$	9.6211
$\frac{5}{8}$	19835	3068	$3\frac{1}{8}$	9.8175
$\frac{11}{16}$	21898	3712	$3\frac{3}{16}$	10.014
$\frac{3}{4}$	23962	4417	$3\frac{1}{4}$	10.210
$\frac{13}{16}$	25525	5185	$3\frac{5}{16}$	10.406
$\frac{7}{8}$	27489	6013	$3\frac{3}{8}$	10.602
1	29452	6963	$3\frac{7}{16}$	10.799
$1\frac{1}{16}$	31416	7854	$3\frac{1}{2}$	10.995
$1\frac{1}{8}$	33379	8866	$3\frac{9}{16}$	11.191
$1\frac{3}{8}$	35343	9940	$3\frac{5}{8}$	11.388
$1\frac{5}{8}$	37306	11075	$3\frac{11}{16}$	11.584
$1\frac{3}{4}$	39270	12271	$3\frac{3}{4}$	11.781
$1\frac{7}{8}$	41233	13530	$3\frac{7}{8}$	11.977
$1\frac{9}{8}$	43197	14848	$3\frac{9}{8}$	12.173
$1\frac{11}{8}$	45160	16229	$3\frac{11}{8}$	12.369
$1\frac{13}{8}$	47124	17671	4	12.566
$1\frac{15}{8}$	49087	19175	$4\frac{1}{16}$	12.762
$1\frac{7}{4}$	51051	20759	$4\frac{1}{8}$	12.959
$1\frac{9}{4}$	53014	22365	$4\frac{3}{16}$	13.155
$1\frac{5}{2}$	54978	24002	$4\frac{1}{4}$	13.351
$1\frac{11}{4}$	56941	25800	$4\frac{3}{8}$	13.547
$1\frac{13}{4}$	58905	27611	$4\frac{5}{16}$	13.744
$1\frac{15}{4}$	60868	29483	$4\frac{1}{2}$	13.940
2	62832	31416	$4\frac{7}{16}$	14.137
$2\frac{1}{16}$	64795	33380	$4\frac{3}{4}$	14.333
$2\frac{1}{8}$	66759	35405	$4\frac{1}{2}$	14.529
$2\frac{3}{8}$	68722	37584	$4\frac{5}{8}$	14.725
$2\frac{1}{2}$	70686	39760	$4\frac{3}{4}$	14.922
$2\frac{5}{8}$	72649	42000	$4\frac{7}{8}$	15.119
$2\frac{3}{4}$	74613	44302	$4\frac{9}{16}$	15.315
$2\frac{7}{8}$	76576	46666	$4\frac{11}{16}$	15.511
$2\frac{9}{8}$	78540	49087	5	15.708

r.	Circum- ference.	Area.	Dia- meter.	Circum- ference.	Area.
	15.904	20.129	9 $\frac{3}{8}$	29.452	69.029
	16.100	20.629	9 $\frac{1}{2}$	29.845	70.882
	16.296	21.135	9 $\frac{5}{8}$	30.237	72.759
	16.493	21.647	9 $\frac{7}{8}$	30.630	74.662
	16.689	22.166	9 $\frac{7}{8}$	31.023	76.588
	16.886	22.690	10	31.416	78.540
	17.082	23.221	10 $\frac{1}{8}$	31.808	80.515
	17.278	23.758	10 $\frac{1}{4}$	32.201	82.516
	17.474	24.301	10 $\frac{3}{8}$	32.594	84.540
	17.671	24.850	10 $\frac{1}{2}$	32.986	86.590
	17.867	25.406	10 $\frac{3}{4}$	33.379	88.664
	18.064	25.967	10 $\frac{7}{8}$	33.772	90.762
	18.261	26.535	10 $\frac{7}{8}$	34.164	92.885
	18.457	27.108	11	34.558	95.033
	18.653	27.688	11 $\frac{1}{8}$	34.950	97.205
	18.849	28.274	11 $\frac{1}{4}$	35.343	99.402
	19.242	29.464	11 $\frac{3}{8}$	35.735	101.623
	19.635	30.679	11 $\frac{1}{2}$	36.128	103.869
	20.027	31.919	11 $\frac{5}{8}$	36.521	106.139
	20.420	33.183	11 $\frac{3}{4}$	36.913	108.434
	20.813	34.471	11 $\frac{7}{8}$	37.306	110.753
	21.205	35.784	12	37.699	113.097
	21.598	37.122	12 $\frac{1}{8}$	38.091	115.466
	21.991	38.484	12 $\frac{1}{4}$	38.484	117.859
	22.383	39.871	12 $\frac{3}{8}$	38.877	120.276
	22.776	41.282	12 $\frac{1}{2}$	39.270	122.718
	23.169	42.718	12 $\frac{5}{8}$	39.662	125.184
	23.562	44.178	12 $\frac{3}{4}$	40.055	127.676
	23.954	45.663	12 $\frac{7}{8}$	40.448	130.192
	24.347	47.173	13	40.840	132.732
	24.740	48.707	13 $\frac{1}{8}$	41.233	135.297
	25.132	50.265	13 $\frac{1}{4}$	41.626	137.886
	25.515	51.848	13 $\frac{3}{8}$	42.018	140.500
	25.918	53.456	13 $\frac{1}{2}$	42.411	143.139
	26.310	55.088	13 $\frac{5}{8}$	42.804	145.802
	26.703	56.745	13 $\frac{3}{4}$	43.197	148.489
	27.096	58.426	13 $\frac{7}{8}$	43.589	151.201
	27.489	60.132	14	43.982	153.938
	27.881	61.862	14 $\frac{1}{8}$	44.375	156.699
	28.274	63.617	14 $\frac{1}{4}$	44.767	159.485
	28.667	65.396	14 $\frac{3}{8}$	45.160	162.295
	29.059	67.200	14 $\frac{1}{2}$	45.553	165.130

Dia- meter	Circum- ference.	Area.	Dia- meter	Circum- ference.	Area.
14 $\frac{1}{2}$	45.215	167.989	19 $\frac{1}{2}$	62.439	310.247
14 $\frac{3}{4}$	46.338	170.873	20	62.832	314.160
14 $\frac{7}{8}$	46.731	173.782	20 $\frac{1}{2}$	63.224	318.099
15	47.124	176.715	20 $\frac{3}{4}$	63.617	322.063
15 $\frac{1}{2}$	47.516	179.672	20 $\frac{7}{8}$	64.010	326.051
15 $\frac{3}{4}$	47.909	182.654	20 $\frac{7}{8}$	64.402	330.061
15 $\frac{7}{8}$	48.302	185.661	20 $\frac{7}{8}$	64.795	334.101
15 $\frac{7}{8}$	48.694	188.692	20 $\frac{7}{8}$	65.188	338.163
15 $\frac{7}{8}$	49.087	191.748	20 $\frac{7}{8}$	65.580	342.250
15 $\frac{7}{8}$	49.480	194.828	21	65.973	346.361
15 $\frac{7}{8}$	49.872	197.933	21 $\frac{1}{8}$	66.366	350.497
16	50.265	201.062	21 $\frac{1}{4}$	66.759	354.657
16 $\frac{1}{2}$	50.658	204.216	21 $\frac{1}{2}$	67.151	358.841
16 $\frac{3}{4}$	51.051	207.394	21 $\frac{3}{4}$	67.544	363.051
16 $\frac{7}{8}$	51.443	210.597	21 $\frac{7}{8}$	67.937	367.284
16 $\frac{7}{8}$	51.836	213.825	21 $\frac{7}{8}$	68.329	371.543
16 $\frac{7}{8}$	52.229	217.077	21 $\frac{7}{8}$	68.722	375.826
16 $\frac{7}{8}$	52.621	220.353	22	69.115	380.133
16 $\frac{7}{8}$	53.014	223.654	22 $\frac{1}{8}$	69.507	384.465
17	53.407	226.980	22 $\frac{1}{4}$	69.900	388.822
17 $\frac{1}{2}$	53.799	230.330	22 $\frac{3}{8}$	70.293	393.203
17 $\frac{3}{4}$	54.192	233.705	22 $\frac{1}{2}$	70.686	397.608
17 $\frac{7}{8}$	54.585	237.104	22 $\frac{3}{4}$	71.078	402.038
17 $\frac{7}{8}$	54.978	240.528	22 $\frac{7}{8}$	71.471	406.493
17 $\frac{7}{8}$	55.370	243.977	22 $\frac{7}{8}$	71.864	410.972
17 $\frac{7}{8}$	55.763	247.450	23	72.256	415.476
17 $\frac{7}{8}$	56.156	250.947	23 $\frac{1}{8}$	72.649	420.004
18	56.548	254.469	23 $\frac{1}{4}$	73.042	424.557
18 $\frac{1}{2}$	56.941	258.016	23 $\frac{3}{8}$	73.434	429.135
18 $\frac{3}{4}$	57.334	261.587	23 $\frac{1}{2}$	73.827	433.731
18 $\frac{7}{8}$	57.726	265.182	23 $\frac{3}{4}$	74.220	438.363
18 $\frac{7}{8}$	58.119	268.803	23 $\frac{7}{8}$	74.613	443.014
18 $\frac{7}{8}$	58.512	272.447	23 $\frac{7}{8}$	75.005	447.699
18 $\frac{7}{8}$	58.905	276.117	24	75.398	452.390
18 $\frac{7}{8}$	59.297	279.811	24 $\frac{1}{8}$	75.791	457.115
18 $\frac{7}{8}$	59.690	283.529	24 $\frac{1}{4}$	76.183	461.864
19 $\frac{1}{2}$	60.083	287.272	24 $\frac{3}{8}$	76.576	466.638
19 $\frac{3}{4}$	60.475	291.039	24 $\frac{1}{2}$	76.969	471.436
19 $\frac{7}{8}$	60.868	294.831	24 $\frac{3}{4}$	77.361	476.259
19 $\frac{7}{8}$	61.261	298.648	24 $\frac{7}{8}$	77.754	481.106
19 $\frac{7}{8}$	61.653	302.489	24 $\frac{7}{8}$	78.147	485.978
19 $\frac{7}{8}$	62.046	306.356	25	78.540	490.875

	0	1	2	3	4	5	6	7	8	9	10
111	43523	44711	46105	47697	49585	51775	54264	57055	60147	63540	67243
112	44921	46306	47898	50080	52568	55358	58448	61839	65232	68925	72918
113	46307	47893	49686	52074	54856	57941	61326	64913	68702	72791	77180
114	47693	49280	50966	53050	55529	58402	61669	65228	69078	73217	77644
115	49078	50665	52351	54532	57197	60254	63702	67540	71667	76082	80784
116	50463	52050	53736	55913	58578	61634	65080	68916	73041	77454	82155
117	51848	53435	55121	57298	59953	63008	66453	70287	74500	79091	83958
118	53232	54819	56505	58680	61334	64387	67838	71679	75900	80500	85398
119	54617	56204	57890	60064	62717	65768	69217	73054	77279	81891	86800
120	55999	57586	59272	61445	64096	67145	70592	74427	78650	83261	88170
121	57383	58970	60656	62828	65478	68525	72070	75903	80024	84533	89440
122	58766	60353	62039	64210	66859	70004	73547	77478	81797	86504	91608
123	59947	61534	63220	65391	68039	71183	74724	78654	82972	87678	92781
124	61332	62919	64605	66776	69423	72566	76107	80036	84353	89058	94161
125	62717	64304	65990	68161	70807	73949	77489	81417	85734	90439	95542
126	64099	65686	67372	69543	72188	75329	78868	82795	87110	91814	96917
127	65483	67070	68756	70927	73571	76712	80251	84178	88493	93196	98299
128	66866	68453	70139	72310	74953	78093	81632	85558	90073	94976	100278
129	68250	69837	71523	73694	76336	79475	83013	86938	91453	96356	101658
130	69633	71220	72906	75076	77717	80855	84392	88317	92831	97734	103036
131	71017	72604	74290	76460	79099	82236	85772	89696	93909	98521	103523
132	72399	73986	75672	77842	80480	83616	87151	91074	95386	100097	105199
133	73783	75370	77056	79226	81863	84997	88530	92452	96763	101473	106575
134	75166	76753	78439	80609	83245	86378	89909	93829	98139	102849	107951
135	76550	78137	79823	81993	84628	87760	91290	95209	99518	104228	109330
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137	79317	80904	82590	84760	87382	90502	94029	97954	102267	106979	112081
138	80699	82286	83972	86142	88763	91882	95409	99333	103645	108357	113459
139	82083	83670	85356	87526	90146	93264	96790	100713	104925	109536	114538
140	83466	85053	86739	88909	91528	94645	98170	102092	106303	110913	115915
141	84850	86437	88123	90293	92909	96024	99548	103469	107679	112189	117191
142	86233	87820	89506	91676	94290	97403	100925	104845	109154	113863	118865
143	87617	89204									

136	133599	133858	134177	134496	134814	135133	135451	135769	136086	136403	316
137	133711	134047	134354	134671	134987	135303	135618	135931	136249	136564	315
138	133879	134227	134539	134851	135163	135475	135787	136099	136411	136722	313
139	134015	134387	134689	135001	135313	135625	135937	136249	136561	136873	311
140	134128	134538	134848	135158	135468	135778	136088	136398	136708	137018	309
141	134219	134657	134983	135309	135635	135961	136287	136613	136939	137265	308
142	134288	134754	135080	135406	135732	136058	136384	136710	137036	137362	304
143	134336	134830	135156	135482	135808	136134	136460	136786	137112	137438	302
144	134382	134904	135230	135556	135882	136208	136534	136860	137186	137512	300
145	134418	134967	135317	135667	136017	136367	136717	137067	137417	137767	298
146	134453	135029	135394	135759	136124	136489	136854	137219	137584	137949	296
147	134487	135081	135458	135835	136212	136589	136966	137343	137720	138097	294
148	134522	135133	135524	135915	136306	136697	137088	137479	137870	138261	292
149	134556	135184	135590	135996	136402	136808	137214	137620	138026	138432	290
150	134591	135234	135655	136076	136497	136918	137339	137760	138181	138602	288
151	134625	135283	135719	136155	136591	137027	137463	137899	138335	138771	286
152	134659	135331	135782	136233	136684	137135	137586	138037	138488	138939	284
153	134693	135380	135846	136312	136778	137244	137710	138176	138642	139108	282
154	134727	135430	135911	136392	136873	137354	137835	138316	138797	139278	281
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156	134795	135536	136048	136560	137072	137584	138096	138608	139120	139632	277
157	134829	135585	136114	136643	137172	137701	138230	138759	139288	139817	276
158	134863	135634	136179	136724	137269	137814	138359	138904	139449	139994	274
159	134897	135683	136244	136805	137366	137927	138488	139049	139610	140171	272
160	134931	135732	136308	136889	137470	138051	138632	139213	139794	140375	270

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161	206826	207096	207365	207634	207904	208173	208441	208710	208979	209247	269
162	209515	209783	210051	210319	210586	210853	211121	211388	211654	211921	267
163	212188	212454	212720	212986	213252	213518	213783	214049	214314	214579	266
164	214844	215109	215373	215638	215902	216166	216430	216694	216957	217221	264
165	217484	217747	218011	218273	218536	218798	219060	219323	219585	219846	263
166	220108	220370	220631	220892	221153	221414	221675	221936	222196	222456	260
167	222716	222976	223236	223496	223755	224015	224274	224533	224792	225051	259
168	225309	225568	225826	226084	226342	226600	226858	227117	227372	227630	257
169	227887	228144	228400	228657	228913	229170	229426	229682	229938	230193	256
170	230449	230704	230959	231215	231470	231724	231979	232234	232488	232742	254
171	232999	233256	233511	233767	234021	234274	234527	234780	235033	235276	253
172	235528	235781	236033	236285	236537	236789	237041	237292	237544	237795	251
173	238046	238297	238548	238799	239049	239299	239550	239800	240050	240300	250
174	240649	240700	241048	241297	241546	241795	242044	242293	242541	242790	249
175	243048	243286	243534	243782	244030	244277	244525	244772	245019	245266	247
176	245513	245759	246006	246252	246499	246745	246991	247237	247482	247728	246
177	247973	248219	248464	248709	248954	249198	249443	249687	249932	250176	244
178	250420	250664	250908	251151	251395	251638	251881	252125	252368	252610	243
179	252858	253096	253338	253580	253822	254064	254306	254548	254790	255031	242
180	255273	255514	255755	255996	256237	256477	256718	256958	257198	257439	240
181	257679	257918	258158	258398	258637	258877	259116	259355	259594	259833	239
182	260071	260310	260548	260787	261025	261263	261501	261739	261976	262214	238
183	262451	262688	262925	263162	263399	263636	263873	264109	264346	264582	236
184	264818	265054	265290	265525	265761	265996	266232	266467	266702	266937	235
185	267172	267406	267641	267875	268110	268344	268578	268812	269046	269279	234

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186	269513	269749	269980	270213	270446	270679	270912	271144	271377	271609	283
187	271842	272074	272306	272538	272770	273001	273233	273464	273696	273927	282
188	274128	274389	27462	274840	275081	275311	275542	275772	276002	276232	280
189	276462	276692	276921	277151	277380	277609	277838	278067	278296	278525	279
190	278754	278982	279211	279439	279664	279895	280123	280351	280578	280806	278
191	281033	281261	281488	281715	281942	282169	282396	282622	282849	283075	277
192	283301	283527	283753	283979	284207	284431	284656	284882	285107	285332	276
193	285557	285782	286007	286232	286456	286681	286907	287131	287354	287578	274
194	287802	288026	288249	288473	288696	288920	289143	289366	289589	289812	273
195	290035	290257	290480	290702	290925	291147	291369	291591	291813	292034	272
196	292256	292478	292699	292920	293141	293363	293584	293804	294025	294246	271
197	294469	294687	294907	295127	295347	295567	295787	296007	296226	296446	270
198	296667	296884	297104	297322	297542	297761	297979	298198	298416	298635	268
199	298858	299071	299289	299507	299727	299943	300161	300378	300595	300813	267
200	301035	301247	301464	301680	301898	302114	302331	302547	302764	302982	266
201	303196	303412	303628	303844	304059	304275	304491	304706	304921	305136	265
202	305351	305566	305781	305997	306211	306427	306639	306854	307068	307282	264
203	307496	307710	307924	308137	308351	308564	308778	308991	309204	309417	263
204	309630	309845	310060	310268	310481	310693	310906	311118	311330	311542	262
205	311754	311966	312177	312389	312606	312812	313023	313234	313445	313656	261
206	313867	314078	314289	314499	314711	314926	315131	315346	315551	315760	260
207	31597	316186	316390	316599	316809	317018	317227	317436	317646	317851	259
208	318063	318272	318481	318689	318898	319106	319314	319522	319731	319938	258
209	320146	320354	320562	320769	320977	321184	321391	321598	321806	322012	257
210	322219	322426	322633	322839	323046	323252	323458	323665	323871	324077	256

Dia- meter.	Circum- ference.	Area.	Dia- meter.	Circum- ference.	Area.
25 $\frac{1}{8}$	78.932	495.796	30 $\frac{3}{8}$	95.426	724.641
25 $\frac{1}{4}$	79.325	500.741	30 $\frac{1}{2}$	95.818	730.618
25 $\frac{3}{8}$	79.718	505.711	30 $\frac{5}{8}$	96.211	736.619
25 $\frac{1}{2}$	80.110	510.706	30 $\frac{3}{4}$	96.604	742.644
25 $\frac{5}{8}$	80.503	515.725	30 $\frac{7}{8}$	96.996	748.694
25 $\frac{3}{4}$	80.896	520.769	31	97.389	754.769
25 $\frac{7}{8}$	81.288	525.837	31 $\frac{1}{8}$	97.782	760.868
26	81.681	530.930	31 $\frac{1}{4}$	98.175	766.992
26 $\frac{1}{8}$	82.074	536.047	31 $\frac{3}{8}$	98.567	773.140
26 $\frac{1}{4}$	82.467	541.189	31 $\frac{1}{2}$	98.968	779.313
26 $\frac{3}{8}$	82.859	546.356	31 $\frac{3}{4}$	99.353	785.510
26 $\frac{1}{2}$	83.252	551.547	31 $\frac{7}{8}$	99.745	791.732
26 $\frac{5}{8}$	83.645	556.762	32	100.138	797.978
26 $\frac{3}{4}$	84.037	562.002	32 $\frac{1}{8}$	100.531	804.249
26 $\frac{7}{8}$	84.430	567.267	32 $\frac{1}{4}$	100.924	810.545
27	84.823	572.556	32 $\frac{3}{8}$	101.316	816.865
27 $\frac{1}{8}$	85.215	577.870	32 $\frac{1}{2}$	101.709	823.209
27 $\frac{1}{4}$	85.608	583.208	32 $\frac{3}{4}$	102.102	829.578
27 $\frac{3}{8}$	86.001	588.571	32 $\frac{5}{8}$	102.494	835.972
27 $\frac{1}{2}$	86.394	593.958	32 $\frac{3}{4}$	102.887	842.390
27 $\frac{5}{8}$	86.786	599.370	32 $\frac{7}{8}$	103.280	848.833
27 $\frac{3}{4}$	87.179	604.807	33	103.672	855.30
27 $\frac{7}{8}$	87.572	610.268	33 $\frac{1}{8}$	104.055	861.79
28	87.964	615.753	33 $\frac{1}{4}$	104.458	868.30
28 $\frac{1}{8}$	88.357	621.263	33 $\frac{3}{8}$	104.850	874.84
28 $\frac{1}{4}$	88.750	626.798	33 $\frac{1}{2}$	105.243	881.41
28 $\frac{3}{8}$	89.142	632.357	33 $\frac{5}{8}$	105.636	888.00
28 $\frac{1}{2}$	89.535	637.941	33 $\frac{3}{4}$	106.029	894.61
28 $\frac{5}{8}$	89.928	643.594	33 $\frac{7}{8}$	106.421	901.25
28 $\frac{3}{4}$	90.321	649.182	34	106.814	907.92
28 $\frac{7}{8}$	90.713	654.839	34 $\frac{1}{8}$	107.207	914.61
29	91.106	660.521	34 $\frac{1}{4}$	107.599	921.32
29 $\frac{1}{8}$	91.499	666.227	34 $\frac{3}{8}$	107.992	928.06
29 $\frac{1}{4}$	91.891	671.958	34 $\frac{1}{2}$	108.385	934.82
29 $\frac{3}{8}$	92.284	677.714	34 $\frac{3}{4}$	108.777	941.60
29 $\frac{1}{2}$	92.677	683.494	34 $\frac{5}{8}$	109.170	948.41
29 $\frac{5}{8}$	93.069	689.298	34 $\frac{7}{8}$	109.563	955.25
29 $\frac{3}{4}$	93.462	695.128	35	109.956	962.11
29 $\frac{7}{8}$	93.855	700.981	35 $\frac{1}{8}$	110.348	968.99
30	94.248	706.860	35 $\frac{1}{4}$	110.741	975.90
30 $\frac{1}{8}$	94.640	712.762	35 $\frac{3}{8}$	111.134	982.84
30 $\frac{1}{4}$	95.033	718.690	35 $\frac{1}{2}$	111.526	989.80

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287	374748	374932	375115	375298	375481	375664	375846	376029	376212	376394	185
288	376567	376749	376932	377112	377296	377488	377670	377852	378034	378216	186
289	378398	378580	378761	378943	379124	379306	379487	379668	379849	380030	187
290	380211	380392	380573	380754	380934	381115	381296	381476	381656	381837	188
291	382017	382197	382377	382557	382737	382917	383097	383277	383456	383636	189
292	383817	383996	384175	384354	384533	384712	384891	385070	385249	385428	190
293	385609	385787	385965	386143	386321	386499	386677	386855	387033	387212	191
294	387390	387568	387746	387923	388101	388279	388456	388634	388811	388989	192
295	389166	389343	389520	389698	389875	390053	390230	390407	390584	390761	193
296	390937	391114	391291	391468	391644	391821	391998	392175	392352	392529	194
297	392697	392873	393049	393225	393401	393577	393753	393929	394105	394281	195
298	394457	394632	394807	394982	395157	395332	395507	395682	395857	396032	196
299	396199	396371	396543	396715	396886	397058	397229	397401	397572	397743	197
300	397914	398085	398256	398427	398598	398769	398940	399111	399282	399453	198
301	399624	399795	399966	400137	400308	400479	400649	400820	400991	401162	199
302	401333	401504	401675	401846	402017	402188	402359	402530	402701	402872	200
303	403043	403214	403385	403556	403727	403898	404069	404240	404411	404582	201
304	404753	404924	405095	405266	405437	405608	405779	405950	406121	406292	202
305	406463	406634	406805	406976	407147	407318	407489	407660	407831	408002	203
306	408173	408344	408515	408686	408857	409028	409199	409370	409541	409712	204
307	409883	410054	410225	410396	410567	410738	410909	411080	411251	411422	205
308	411593	411764	411935	412106	412277	412448	412619	412790	412961	413132	206
309	413303	413474	413645	413816	413987	414158	414329	414500	414671	414842	207
310	414973	415144	415315	415486	415657	415828	415999	416170	416341	416512	208

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261	416641	416807	416973	417139	417306	417472	417638	417804	417970	418137	166
262	418305	418467	418633	418798	418964	419129	419295	419460	419625	419791	165
263	419956	420121	420286	420451	420616	420781	420947	421110	421275	421439	165
264	421604	421768	421933	422097	422261	422426	422590	422754	422918	423082	164
265	423246	423410	423574	423737	423901	424065	424228	424392	424556	424718	163
266	424882	425045	425208	425371	425534	425697	425860	426023	426186	426349	163
267	426511	426674	426836	426999	427161	427324	427486	427648	427811	427973	162
268	428135	428297	428459	428621	428783	428944	429106	429268	429429	429591	162
269	429752	429914	430075	430236	430398	430559	430720	430881	431042	431203	161
270	431374	431525	431687	431848	432007	432167	432328	432488	432649	432809	160
271	432969	433128	433289	433449	433610	433770	433930	434090	434249	434409	160
272	434569	434729	434888	435048	435207	435367	435526	435685	435844	436004	159
273	436163	436322	436481	436640	436799	436957	437116	437275	437433	437592	159
274	437751	437909	438067	438226	438384	438542	438701	438859	439017	439175	158
275	439333	439491	439648	439806	439964	440122	440279	440437	440594	440752	157
276	440909	441066	441221	441381	441538	441695	441852	442009	442166	442323	157
277	442480	442637	442793	442950	443106	443263	443419	443576	443732	443889	156
278	444040	444201	444357	444513	444669	444825	444981	445137	445293	445449	156
279	445604	445760	445915	446071	446226	446382	446537	446692	446848	447003	155
280	447158	447313	447468	447623	447778	447933	448088	448242	448397	448552	155
281	448706	448861	449015	449170	449324	449478	449633	449787	449941	450095	154
282	450249	450403	450557	450711	450865	451018	451172	451326	451479	451633	154
283	451785	451940	452095	452247	452400	452553	452706	452859	453012	453165	153
284	453318	453471	453624	453777	453930	454082	454235	454387	454540	454692	153
285	454845	454997	455150	455302	455454	455606	455758	455910	456062	456214	152
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287	450382	450393	450444	450395	450447	450498	450549	450600	450651	450702	139
288	450392	450403	450454	450405	450457	450508	450559	450610	450661	450712	140
289	450408	450418	450469	450420	450471	450522	450573	450624	450675	450726	141
290	450428	450438	450489	450440	450491	450542	450593	450644	450695	450746	142
291	450448	450458	450509	450460	450511	450562	450613	450664	450715	450766	143
292	450468	450478	450529	450480	450531	450582	450633	450684	450735	450786	144
293	450488	450498	450549	450500	450551	450602	450653	450704	450755	450806	145
294	450508	450518	450569	450520	450571	450622	450673	450724	450775	450826	146
295	450528	450538	450589	450540	450591	450642	450693	450744	450795	450846	147
296	450548	450558	450609	450560	450611	450662	450713	450764	450815	450866	148
297	450568	450578	450629	450580	450631	450682	450733	450784	450835	450886	149
298	450588	450598	450649	450600	450651	450702	450753	450804	450855	450906	150
299	450608	450618	450669	450620	450671	450722	450773	450824	450875	450926	151
300	450628	450638	450689	450640	450691	450742	450793	450844	450895	450946	152
301	450648	450658	450709	450660	450711	450762	450813	450864	450915	450966	153
302	450668	450678	450729	450680	450731	450782	450833	450884	450935	450986	154
303	450688	450698	450749	450700	450751	450802	450853	450904	450955	451006	155
304	450708	450718	450769	450720	450771	450822	450873	450924	450975	451026	156
305	450728	450738	450789	450740	450791	450842	450893	450944	450995	451046	157
306	450748	450758	450809	450760	450811	450862	450913	450964	451015	451066	158
307	450768	450778	450829	450780	450831	450882	450933	450984	451035	451086	159
308	450788	450798	450849	450800	450851	450902	450953	451004	451055	451106	160
309	450808	450818	450869	450820	450871	450922	450973	451024	451075	451126	161
310	450828	450838	450889	450840	450891	450942	450993	451044	451095	451146	162

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312	494156	494294	494433	494572	494711	494850	494989	495128	495267	495406	139
313	495544	495683	495822	495960	496099	496238	496376	496515	496653	496791	139
314	496930	497068	497206	497344	497483	497621	497759	497897	498035	498173	139
315	498311	498448	498586	498724	498862	498999	499137	499275	499412	499550	139
316	499687	499824	499962	500100	500238	500374	500511	500648	500786	500922	137
317	501059	501196	501333	501470	501607	501744	501880	502017	502154	502291	137
318	502427	502564	502700	502837	502973	503109	503246	503382	503518	503655	136
319	503791	503927	504063	504199	504335	504471	504607	504743	504878	505014	136
320	505150	505286	505421	505557	505693	505828	505964	506099	506234	506370	136
321	506505	506640	506776	506911	507046	507181	507316	507451	507586	507721	135
322	507851	507984	508126	508260	508395	508530	508664	508799	508933	509068	135
323	509203	509337	509471	509606	509740	509874	510009	510143	510277	510411	134
324	510545	510679	510813	510947	511081	511215	511349	511482	511616	511750	134
325	511883	512017	512151	512284	512418	512551	512684	512818	512951	513084	133
326	513218	513351	513484	513617	513750	513883	514016	514149	514282	514415	133
327	514548	514681	514813	514946	515079	515211	515344	515476	515609	515741	133
328	515874	516006	516139	516271	516403	516535	516668	516800	516932	517064	132
329	517196	517328	517460	517592	517724	517855	517987	518119	518251	518382	132
330	518514	518646	518777	518909	519040	519171	519303	519434	519566	519697	131
331	519828	519959	520090	520221	520353	520484	520615	520747	520878	521007	131
332	521138	521269	521400	521530	521661	521792	521922	522053	522183	522314	131
333	522444	522573	522705	522835	522966	523096	523226	523356	523486	523616	130
334	523746	523876	524006	524136	524266	524396	524526	524656	524785	524915	130
335	525045	525174	525301	525434	525563	525693	525822	525951	526081	526210	129
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836	526339	526449	526548	526677	526876	526985	527114	527243	527372	129
837	527380	527559	527888	528016	528145	528274	528402	528531	528660	129
838	528917	529055	529174	529302	529430	529559	529687	529815	529943	128
839	530206	530329	530459	530584	530712	530840	530968	531106	531225	128
840	531479	531607	531734	531862	531990	532117	532245	532372	532500	128
841	532704	532882	533009	533136	533264	533391	533518	533645	533772	127
842	534026	534153	534280	534407	534534	534661	534787	534914	535041	127
843	535294	535421	535547	535674	535800	535927	536053	536179	536306	126
844	536558	53668	536811	536937	537063	537189	537315	537441	537567	126
845	537879	537947	538071	538197	538322	538448	538574	538699	538825	126
846	539076	539202	539327	539452	539578	539703	539829	539954	540079	125
847	540329	540455	540580	540705	540830	540955	541080	541205	541330	125
848	541579	541704	541829	541955	542078	542203	542327	542452	542576	125
849	542825	542950	543074	543199	543323	543447	543571	543696	543820	124
850	544068	544192	544316	544440	544564	544688	544812	544936	545060	124
851	545307	545431	545555	545678	545802	545925	546049	546172	546296	124
852	546643	546666	546789	546913	547036	547159	547282	547405	547529	123
853	547777	547898	548021	548145	548267	548389	548512	548635	548758	123
854	549003	549126	549249	549371	549494	549616	549739	549861	549984	123
855	550228	550351	550473	550596	550717	550839	550962	551084	551206	122
856	551110	551232	551354	551476	551598	551720	551841	551963	552085	122
857	552268	552390	552511	552633	552754	552876	552998	553119	553241	121
858	553885	554004	554126	554247	554368	554489	554610	554731	554852	121
859	555094	555215	555336	555457	555578	555699	555820	555941	556061	121
860	556353	556423	556544	556664	556785	556905	557026	557146	557267	120

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361	55507	55607	55748	55808	557988	558108	558228	558119	558469	558799	120
362	558709	558829	558948	559068	559188	559308	559428	559548	559667	559787	120
363	559307	559426	559546	559667	559785	559904	560024	560143	560263	560382	119
364	560107	560221	560340	560459	560578	560698	560817	560936	561055	561174	119
365	560293	560412	560531	560651	560770	560887	561006	561125	561244	561362	119
366	560481	560600	560718	560837	560955	561074	561192	561311	561429	561548	119
367	560666	560784	560903	561021	561139	561257	561376	561494	561612	561730	118
368	560848	560966	561084	561203	561320	561437	561555	561673	561791	561909	118
369	561026	561144	561262	561379	561497	561614	561732	561849	561967	562084	118
370	561202	561319	561436	561554	561671	561788	561905	562023	562140	562257	117
371	561374	561491	561608	561725	561842	561959	562076	562193	562309	562426	117
372	561543	561660	561777	561893	562010	562126	562243	562359	562476	562592	117
373	561709	561825	561942	562058	562174	562291	562407	562523	562639	562755	116
374	561872	561988	562104	562220	562335	562452	562568	562684	562800	562915	116
375	562031	562147	562263	562379	562494	562610	562726	562841	562957	563072	116
376	562188	562303	562419	562534	562650	562765	562880	562996	563111	563226	116
377	562341	562457	562572	562687	562802	562917	563032	563147	563262	563377	115
378	562492	562607	562722	562836	562951	563066	563181	563295	563410	563525	115
379	562639	562754	562868	562983	563097	563212	563326	563441	563555	563669	114
380	562784	562898	563012	563126	563241	563355	563469	563583	563697	563811	114
381	562925	563039	563153	563267	563381	563495	563608	563722	563836	563950	114
382	563068	563177	563291	563404	563518	563631	563745	563858	563972	564085	114
383	563219	563332	563446	563559	563672	563785	563897	564010	564123	564238	113
384	563361	563474	563587	563699	563813	563926	564039	564152	564265	564378	113
385	563501	563614	563726	563839	563952	564065	564177	564290	564403	564515	113

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386	587487	587506	587525	587544	587563	587582	587601	587620	587639	587658	112
387	587711	587730	587749	587768	587787	587806	587825	587844	587863	587882	112
388	587892	587911	587930	587949	587968	587987	588006	588025	588044	588063	112
389	588072	588091	588110	588129	588148	588167	588186	588205	588224	588243	112
390	588252	588271	588290	588309	588328	588347	588366	588385	588404	588423	111
391	588432	588451	588470	588489	588508	588527	588546	588565	588584	588603	111
392	588612	588631	588650	588669	588688	588707	588726	588745	588764	588783	111
393	588792	588811	588830	588849	588868	588887	588906	588925	588944	588963	110
394	588972	588991	589010	589029	589048	589067	589086	589105	589124	589143	110
395	589152	589171	589190	589209	589228	589247	589266	589285	589304	589323	110
396	589332	589351	589370	589389	589408	589427	589446	589465	589484	589503	110
397	589512	589531	589550	589569	589588	589607	589626	589645	589664	589683	109
398	589692	589711	589730	589749	589768	589787	589806	589825	589844	589863	109
399	589872	589891	589910	589929	589948	589967	589986	590005	590024	590043	109
400	590052	590071	590090	590109	590128	590147	590166	590185	590204	590223	108
401	590232	590251	590270	590289	590308	590327	590346	590365	590384	590403	108
402	590412	590431	590450	590469	590488	590507	590526	590545	590564	590583	108
403	590592	590611	590630	590649	590668	590687	590706	590725	590744	590763	107
404	590772	590791	590810	590829	590848	590867	590886	590905	590924	590943	107
405	590952	590971	590990	591009	591028	591047	591066	591085	591104	591123	107
406	591132	591151	591170	591189	591208	591227	591246	591265	591284	591303	107
407	591312	591331	591350	591369	591388	591407	591426	591445	591464	591483	106
408	591492	591511	591530	591549	591568	591587	591606	591625	591644	591663	106
409	591672	591691	591710	591729	591748	591767	591786	591805	591824	591843	106
410	591852	591871	591890	591909	591928	591947	591966	591985	592004	592023	106

Dia- meter.	Circum- ference.	Area.	Dia- meter.	Circum- ference.	Area.
63 $\frac{1}{4}$	198.706	3142.04	73 $\frac{1}{4}$	231.693	4271.83
63 $\frac{1}{2}$	199.491	3166.92	74	232.478	4300.84
63 $\frac{3}{4}$	200.277	3191.91	74 $\frac{1}{4}$	233.263	4329.95
64	201.062	3216.99	74 $\frac{1}{2}$	234.049	4359.16
64 $\frac{1}{4}$	201.847	3242.17	74 $\frac{3}{4}$	234.834	4388.47
64 $\frac{1}{2}$	202.633	3267.46	75	235.620	4417.86
64 $\frac{3}{4}$	203.418	3292.83	75 $\frac{1}{4}$	236.405	4447.37
65	204.204	3318.31	75 $\frac{1}{2}$	237.190	4476.97
65 $\frac{1}{4}$	204.989	3343.88	75 $\frac{3}{4}$	237.976	4506.67
65 $\frac{1}{2}$	205.774	3369.56	76	238.761	4536.46
65 $\frac{3}{4}$	206.560	3395.33	76 $\frac{1}{4}$	239.547	4566.36
66	207.345	3421.19	76 $\frac{1}{2}$	240.332	4596.35
66 $\frac{1}{4}$	208.131	3447.16	76 $\frac{3}{4}$	241.117	4626.44
66 $\frac{1}{2}$	208.916	3473.23	77	241.903	4656.63
66 $\frac{3}{4}$	209.701	3499.39	77 $\frac{1}{4}$	242.688	4686.92
67	210.487	3525.66	77 $\frac{1}{2}$	243.474	4717.30
67 $\frac{1}{4}$	211.272	3552.01	77 $\frac{3}{4}$	244.259	4747.79
67 $\frac{1}{2}$	212.058	3578.47	78	245.044	4778.36
67 $\frac{3}{4}$	212.843	3605.03	78 $\frac{1}{4}$	245.830	4809.05
68	213.628	3631.68	78 $\frac{1}{2}$	246.615	4839.83
68 $\frac{1}{4}$	214.414	3658.44	78 $\frac{3}{4}$	247.401	4870.70
68 $\frac{1}{2}$	215.199	3685.29	79	248.186	4901.68
68 $\frac{3}{4}$	215.985	3712.24	79 $\frac{1}{4}$	248.971	4932.75
69	216.770	3739.28	79 $\frac{1}{2}$	249.757	4963.92
69 $\frac{1}{4}$	217.555	3766.43	79 $\frac{3}{4}$	250.542	4995.19
69 $\frac{1}{2}$	218.341	3793.67	80	251.328	5026.55
69 $\frac{3}{4}$	219.126	3821.02	80 $\frac{1}{4}$	252.113	5058.00
70	219.912	3848.45	80 $\frac{1}{2}$	252.898	5089.58
70 $\frac{1}{4}$	220.697	3875.99	80 $\frac{3}{4}$	253.683	5121.22
70 $\frac{1}{2}$	221.482	3903.63	81	254.469	5153.00
70 $\frac{3}{4}$	222.268	3931.36	81 $\frac{1}{4}$	255.254	5184.84
71	223.053	3959.19	81 $\frac{1}{2}$	256.040	5216.82
71 $\frac{1}{4}$	223.839	3987.13	81 $\frac{3}{4}$	256.825	5248.84
71 $\frac{1}{2}$	224.624	4015.16	82	257.611	5281.02
71 $\frac{3}{4}$	225.409	4043.28	82 $\frac{1}{4}$	258.396	5313.28
72	226.195	4071.50	82 $\frac{1}{2}$	259.182	5345.62
72 $\frac{1}{4}$	226.980	4099.83	82 $\frac{3}{4}$	259.967	5378.04
72 $\frac{1}{2}$	227.766	4128.25	83	260.752	5410.61
72 $\frac{3}{4}$	228.551	4156.77	83 $\frac{1}{4}$	261.537	5443.24
73	229.336	4185.39	83 $\frac{1}{2}$	262.323	5476.00
73 $\frac{1}{4}$	230.122	4214.11	83 $\frac{3}{4}$	263.108	5508.84
73 $\frac{1}{2}$	230.907	4242.92	84	263.894	5541.77

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436	639486	639586	639686	639785	639885	639984	640084	640183	640283	640382	100
437	640481	640581	640680	640779	640879	640978	641077	641177	641276	641375	99
438	641474	641573	641672	641771	641871	641970	642069	642168	642267	642366	99
439	642474	642573	642672	642771	642860	642959	643058	643156	643255	643354	99
440	643453	643551	643650	643749	643847	643946	644044	644143	644242	644340	98
441	644439	644537	644636	644734	644832	644931	645029	645127	645226	645324	98
442	645422	645521	645619	645717	645815	645913	646011	646110	646208	646306	98
443	646404	646502	646600	646698	646796	646894	646992	647089	647187	647285	98
444	647383	647481	647579	647676	647774	647872	647969	648067	648165	648262	98
445	648360	648458	648555	648653	648750	648848	648945	649043	649140	649237	97
446	649335	649432	649530	649627	649724	649821	649919	650016	650113	650210	97
447	650308	650405	650502	650599	650696	650793	650890	650987	651084	651181	97
448	651278	651375	651471	651568	651665	651762	651859	651956	652053	652150	97
449	652245	652343	652440	652537	652633	652730	652826	652923	653019	653116	97
450	653213	653309	653405	653502	653598	653695	653791	653888	653984	654080	96
451	654177	654273	654369	654465	654562	654658	654754	654850	654946	655042	96
452	655138	655235	655331	655427	655523	655619	655715	655810	655906	656002	96
453	656098	656194	656290	656386	656482	656577	656673	656769	656864	656960	96
454	657055	657151	657247	657343	657438	657534	657629	657725	657820	657916	96
455	658011	658107	658202	658298	658393	658488	658584	658679	658774	658870	95
456	658965	659060	659155	659250	659346	659441	659536	659631	659726	659821	95
457	659916	660011	660106	660201	660296	660391	660486	660581	660676	660771	95
458	660865	660960	661055	661150	661245	661339	661434	661529	661623	661718	95
459	661813	661907	662002	662096	662191	662285	662380	662475	662569	662663	94
460	662758	662852	662947	663041	663136	663230	663324	663418	663512	663607	94
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461	66379	66388	66393	66407	66417	66426	66430	66434	66438	66441
462	66442	66450	66454	66468	66478	66486	66490	66493	66497	66500
463	66501	66509	66512	66526	66536	66543	66547	66551	66554	66557
464	66561	66569	66572	66586	66596	66603	66607	66611	66614	66617
465	66621	66629	66632	66646	66656	66663	66667	66671	66674	66677
466	66681	66689	66692	66706	66716	66723	66727	66731	66734	66737
467	66741	66749	66752	66766	66776	66783	66787	66791	66794	66797
468	66801	66809	66812	66826	66836	66843	66847	66851	66854	66857
469	66861	66869	66872	66886	66896	66903	66907	66911	66914	66917
470	66921	66929	66932	66946	66956	66963	66967	66971	66974	66977
471	66981	66989	66992	67006	67016	67023	67027	67031	67034	67037
472	67041	67049	67052	67066	67076	67083	67087	67091	67094	67097
473	67101	67109	67112	67126	67136	67143	67147	67151	67154	67157
474	67161	67169	67172	67186	67196	67203	67207	67211	67214	67217
475	67221	67229	67232	67246	67256	67263	67267	67271	67274	67277
476	67281	67289	67292	67306	67316	67323	67327	67331	67334	67337
477	67341	67349	67352	67366	67376	67383	67387	67391	67394	67397
478	67401	67409	67412	67426	67436	67443	67447	67451	67454	67457
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482	67641	67649	67652	67666	67676	67683	67687	67691	67694	67697
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268	·003731	310	·003226	352	·002841	394	·002538
269	·003717	311	·003215	353	·002833	395	·002532
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271	·003690	313	·003195	355	·002817	397	·002519
272	·003676	314	·003185	356	·002809	398	·002513
273	·003663	315	·003175	357	·002801	399	·002506
274	·003650	316	·003165	358	·002793	400	·002500
275	·003636	317	·003155	359	·002786	401	·002494
276	·003623	318	·003145	360	·002778	402	·002488
277	·003610	319	·003135	361	·002770	403	·002481
278	·003597	320	·003125	362	·002762	404	·002475
279	·003584	321	·003115	363	·002755	405	·002469
280	·003571	322	·003106	364	·002747	406	·002463
281	·003559	323	·003096	365	·002740	407	·002457
282	·003546	324	·003086	366	·002732	408	·002451
283	·003534	325	·003077	367	·002725	409	·002445
284	·003522	326	·003067	368	·002717	410	·002439
285	·003509	327	·003058	369	·002710	411	·002433
286	·003497	328	·003049	370	·002703	412	·002427
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288	·003472	330	·003030	372	·002688	414	·002415
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627	797268	797337	797406	797475	797545	797614	797683	797752	797821	797890	69
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671	820766	820772	820778	820783	820789	820795	820800	820806	820812	820817	65
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710	850897	850959	851021	851083	851145	851207	851269	851331	851393	851455	61

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713	863690	863781	863872	863963	864054	864145	864236	864327	864418	864509	61
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715	865510	865601	865692	865783	865874	865965	866056	866147	866238	866329	61
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717	867330	867421	867512	867603	867694	867785	867876	867967	868058	868149	61
718	868240	868331	868422	868513	868604	868695	868786	868877	868968	869059	60
719	869150	869241	869332	869423	869514	869605	869696	869787	869878	869969	60
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727	876430	876521	876612	876703	876794	876885	876976	877067	877158	877249	60
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729	878250	878341	878432	878523	878614	878705	878796	878887	878978	879069	60
730	879160	879251	879342	879433	879524	879615	879706	879797	879888	879979	59
731	880070	880161	880252	880343	880434	880525	880616	880707	880798	880889	59
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733	881890	881981	882072	882163	882254	882345	882436	882527	882618	882709	59
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741	869818	869877	869935	869994	870053	870111	870170	870228	870287	870345	59
742	870404	870462	870521	870579	870638	870696	870755	870813	870872	870930	58
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747	873321	873379	873437	873495	873553	873611	873669	873727	873785	873844	58
748	873902	873960	874018	874076	874134	874192	874250	874308	874366	874424	58
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752	876218	876276	876333	876391	876449	876507	876564	876622	876680	876737	58
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754	877371	877429	877487	877544	877602	877659	877717	877774	877832	877889	58
755	877917	878004	878062	878119	878177	878234	878292	878349	878407	878464	57
756	878522	878579	878637	878694	878752	878809	878866	878924	878981	879039	57
757	879096	879153	879211	879268	879325	879383	879440	879497	879555	879612	57
758	879669	879726	879784	879841	879898	879956	880013	880070	880127	880185	57
759	880242	880299	880356	880413	880471	880528	880585	880642	880699	880756	57
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763	81962	81988	82014	82040	82066	82092	82118	82144	82170	82196	82222
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766	82820	82846	82872	82898	82924	82950	82976	83002	83028	83054	83080
767	83106	83132	83158	83184	83210	83236	83262	83288	83314	83340	83366
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770	83964	83990	84016	84042	84068	84094	84120	84146	84172	84198	84224
771	84250	84276	84302	84328	84354	84380	84406	84432	84458	84484	84510
772	84536	84562	84588	84614	84640	84666	84692	84718	84744	84770	84796
773	84822	84848	84874	84900	84926	84952	84978	85004	85030	85056	85082
774	85108	85134	85160	85186	85212	85238	85264	85290	85316	85342	85368
775	85394	85420	85446	85472	85498	85524	85550	85576	85602	85628	85654
776	85680	85706	85732	85758	85784	85810	85836	85862	85888	85914	85940
777	85966	85992	86018	86044	86070	86096	86122	86148	86174	86200	86226
778	86252	86278	86304	86330	86356	86382	86408	86434	86460	86486	86512
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781	87110	87136	87162	87188	87214	87240	87266	87292	87318	87344	87370
782	87396	87422	87448	87474	87500	87526	87552	87578	87604	87630	87656
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237	374748	374932	375115	375298	375481	375664	375846	376029	376212	376394	183
238	376777	376959	377141	377324	377506	377688	377870	378052	378234	378416	182
239	378598	378780	378961	379143	379324	379506	379687	379868	380049	380230	181
240	380211	380392	380573	380754	380934	381115	381296	381476	381656	381837	181
241	382017	382197	382377	382557	382737	382917	383097	383277	383456	383636	179
242	383815	383995	384171	384353	384535	384712	384891	385070	385249	385428	179
243	385606	385785	385961	386142	386321	386499	386677	386856	387034	387212	178
244	387396	387568	387746	387923	388101	388279	388456	388634	388811	388989	177
245	389369	389548	389725	389908	390087	390268	390445	390628	390802	390978	177
246	391235	391412	391588	391764	391941	392117	392293	392469	392645	392821	176
247	392997	393173	393348	393524	393699	393875	394051	394226	394401	394577	175
248	394752	394927	395102	395277	395452	395626	395801	395976	396150	396325	175
249	396505	396679	396854	397028	397202	397376	397550	397724	397898	398072	174
250	398246	398420	398594	398768	398942	399115	399289	399463	399637	399810	173
251	399984	400157	400330	400503	400676	400849	401021	401194	401366	401538	173
252	401711	401883	402055	402227	402399	402571	402743	402915	403087	403259	172
253	403431	403602	403773	403944	404115	404286	404457	404628	404799	404970	171
254	405141	405311	405482	405652	405823	405993	406164	406334	406505	406675	171
255	406846	407016	407186	407356	407526	407696	407866	408036	408206	408376	170
256	408546	408716	408886	409056	409226	409396	409566	409736	409906	410076	169
257	410246	410416	410586	410756	410926	411096	411266	411436	411606	411776	169
258	411946	412116	412286	412456	412626	412796	412966	413136	413306	413476	168
259	413646	413816	413986	414156	414326	414496	414666	414836	415006	415176	167
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811	909621	909974	910128	910184	910237	910289	910342	910394	910449	910503	54
812	909976	910031	910084	910140	910170	910223	910277	910330	910384	910437	55
813	910041	910114	910157	910251	910304	910358	910411	910464	910518	910571	56
814	910024	910078	910133	910184	910238	910291	910344	910398	910451	910504	57
815	911118	911211	911264	911317	911371	911421	911477	911530	911584	911637	58
816	911561	911713	911767	911850	911903	911956	912009	912063	912116	912169	59
817	912222	912275	912328	912381	912433	912488	912541	912594	912647	912700	60
818	912755	912806	912859	912911	912966	913019	913072	913125	913178	913231	61
819	913284	913337	913390	913443	913496	913549	913602	913655	913708	913761	62
820	913814	913867	913920	913972	914026	914079	914132	914184	914237	914290	63
821	914348	914401	914449	914502	914555	914608	914660	914713	914766	914819	64
822	914872	914925	914977	915030	915083	915136	915189	915241	915294	915347	65
823	915400	915453	915505	915558	915611	915664	915716	915769	915822	915875	66
824	915927	915980	916033	916085	916138	916191	916243	916296	916349	916401	67
825	916454	916507	916559	916612	916664	916717	916770	916822	916875	916927	68
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827	917506	917558	917611	917663	917716	917768	917820	917873	917925	917978	70
828	918030	918083	918135	918188	918240	918293	918345	918397	918450	918502	71
829	918555	918607	918659	918712	918764	918816	918869	918921	918973	919026	72
830	919078	919130	919183	919235	919287	919340	919392	919444	919496	919549	73
831	919601	919653	919706	919758	919810	919862	919914	919967	920019	920071	74
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838	922344	922396	922448	922500	922551	922603	922655	922707	922758	922810	60
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840	922480	922531	922583	922635	922686	922738	922789	922841	922892	922944	62
841	922548	922599	922651	922702	922754	922805	922856	922908	922959	923010	63
842	922616	922667	922718	922769	922820	922871	922922	922973	923024	923075	64
843	922684	922735	922786	922837	922888	922939	922990	923041	923092	923143	65
844	922752	922803	922854	922905	922956	923007	923058	923109	923159	923210	66
845	922820	922871	922922	922973	923024	923075	923126	923177	923228	923278	67
846	922888	922939	922990	923041	923092	923143	923194	923245	923296	923346	68
847	922956	923007	923058	923109	923159	923210	923261	923312	923363	923413	69
848	923024	923075	923126	923177	923228	923278	923329	923380	923431	923481	70
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851	923228	923278	923329	923380	923431	923481	923532	923582	923633	923683	73
852	923296	923346	923397	923448	923498	923549	923599	923650	923700	923751	74
853	923363	923413	923464	923514	923565	923615	923666	923716	923767	923817	75
854	923431	923481	923532	923582	923633	923683	923734	923784	923835	923885	76
855	923498	923549	923599	923650	923700	923751	923801	923852	923902	923953	77
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857	923633	923683	923734	923784	923835	923885	923936	923986	924037	924087	79
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878	9436714	9436725	9436736	9436747	9436758	9436769	9436780	9436791	9436802	9436813	49
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882	9437114	9437125	9437136	9437147	9437158	9437169	9437180	9437191	9437202	9437213	49
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884	9437314	9437325	9437336	9437347	9437358	9437369	9437380	9437391	9437402	9437413	49
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887	9437614	9437625	9437636	9437647	9437658	9437669	9437680	9437691	9437702	9437713	49
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893	9438214	9438225	9438236	9438247	9438258	9438269	9438280	9438291	9438302	9438313	49
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[illegible]

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464	666518	666612	666705	666799	666892	666986	667079	667173	667266	667360	94
465	667453	667546	667640	667733	667826	667920	668013	668106	668199	668293	93
466	668386	668479	668572	668665	668759	668852	668945	669038	669131	669224	93
467	669317	669410	669503	669596	669689	669782	669875	669967	670060	670153	93
468	670246	670339	670431	670524	670617	670710	670802	670895	670988	671080	93
469	671173	671265	671358	671451	671543	671636	671728	671821	671913	672005	92
470	672098	672190	672283	672375	672467	672560	672652	672744	672836	672929	92
471	673021	673113	673205	673297	673390	673482	673574	673666	673758	673850	92
472	673942	674034	674126	674218	674310	674402	674494	674586	674677	674769	92
473	674861	674953	675045	675137	675228	675320	675412	675503	675595	675687	92
474	675778	675870	675962	676053	676145	676236	676328	676419	676511	676602	92
475	676694	676785	676876	676968	677059	677151	677242	677333	677424	677516	91
476	677607	677698	677789	677881	677972	678063	678154	678245	678336	678427	91
477	678518	678609	678700	678791	678882	678973	679064	679155	679246	679337	91
478	679428	679519	679610	679700	679791	679882	679973	680063	680154	680245	91
479	680336	680426	680517	680607	680698	680789	680879	680970	681060	681151	91
480	681241	681332	681422	681513	681603	681693	681784	681874	681964	682055	90
481	682145	682235	682326	682416	682506	682596	682686	682777	682867	682957	90
482	683047	683137	683227	683317	683407	683497	683587	683677	683767	683857	90
483	683947	684037	684127	684217	684307	684396	684486	684576	684666	684756	90
484	684845	684935	685025	685114	685204	685294	685383	685473	685568	685652	90
485	685742	685831	685921	686010	686100	686189	686279	686368	686458	686547	90
N.	0	1	2	3	4	5	6	7	8	9	D.

HYPERBOLIC LOGARITHMS.

821

N.	Log.	N.	Log.	N.	Log.	N.	Log.
2.65	.9746	3.08	1.1249	3.51	1.2556	3.94	1.3712
2.66	.9783	3.09	1.1282	3.52	1.2585	3.95	1.3737
2.67	.9821	3.10	1.1314	3.53	1.2613	3.96	1.3762
2.68	.9858	3.11	1.1346	3.54	1.2641	3.97	1.3788
2.69	.9895	3.12	1.1378	3.55	1.2669	3.98	1.3813
2.70	.9933	3.13	1.1410	3.56	1.2698	3.99	1.3838
2.71	.9969	3.14	1.1442	3.57	1.2726	4.00	1.3863
2.72	1.0006	3.15	1.1474	3.58	1.2754	4.01	1.3888
2.73	1.0043	3.16	1.1506	3.59	1.2782	4.02	1.3913
2.74	1.0080	3.17	1.1537	3.60	1.2809	4.03	1.3938
2.75	1.0116	3.18	1.1569	3.61	1.2837	4.04	1.3962
2.76	1.0152	3.19	1.1600	3.62	1.2865	4.05	1.3987
2.77	1.0188	3.20	1.1632	3.63	1.2892	4.06	1.4012
2.78	1.0225	3.21	1.1663	3.64	1.2920	4.07	1.4036
2.79	1.0260	3.22	1.1694	3.65	1.2947	4.08	1.4061
2.80	1.0296	3.23	1.1725	3.66	1.2975	4.09	1.4085
2.81	1.0332	3.24	1.1756	3.67	1.3002	4.10	1.4110
2.82	1.0367	3.25	1.1787	3.68	1.3029	4.11	1.4134
2.83	1.0403	3.26	1.1817	3.69	1.3056	4.12	1.4159
2.84	1.0438	3.27	1.1848	3.70	1.3083	4.13	1.4183
2.85	1.0473	3.28	1.1878	3.71	1.3110	4.14	1.4207
2.86	1.0508	3.29	1.1909	3.72	1.3137	4.15	1.4231
2.87	1.0543	3.30	1.1939	3.73	1.3164	4.16	1.4255
2.88	1.0578	3.31	1.1969	3.74	1.3191	4.17	1.4279
2.89	1.0613	3.32	1.1999	3.75	1.3218	4.18	1.4303
2.90	1.0647	3.33	1.2030	3.76	1.3244	4.19	1.4327
2.91	1.0682	3.34	1.2060	3.77	1.3271	4.20	1.4351
2.92	1.0716	3.35	1.2090	3.78	1.3297	4.21	1.4375
2.93	1.0750	3.36	1.2119	3.79	1.3324	4.22	1.4398
2.94	1.0784	3.37	1.2149	3.80	1.3350	4.23	1.4422
2.95	1.0818	3.38	1.2179	3.81	1.3376	4.24	1.4446
2.96	1.0852	3.39	1.2208	3.82	1.3403	4.25	1.4469
2.97	1.0886	3.40	1.2238	3.83	1.3429	4.26	1.4493
2.98	1.0919	3.41	1.2267	3.84	1.3455	4.27	1.4516
2.99	1.0953	3.42	1.2296	3.85	1.3481	4.28	1.4540
3.00	1.0987	3.43	1.2326	3.86	1.3507	4.29	1.4563
3.01	1.1019	3.44	1.2355	3.87	1.3533	4.30	1.4587
3.02	1.1053	3.45	1.2384	3.88	1.3558	4.31	1.4610
3.03	1.1086	3.46	1.2413	3.89	1.3584	4.32	1.4633
3.04	1.1119	3.47	1.2442	3.90	1.3610	4.33	1.4656
3.05	1.1151	3.48	1.2470	3.91	1.3637	4.34	1.4679
3.06	1.1184	3.49	1.2499	3.92	1.3663	4.35	1.4702
3.07	1.1217	3.50	1.2528	3.93	1.3686	4.36	1.4725

No.	Log.	N	Log.	No.	Log.	No.	Log.
4 37	1 4748	4 80	1 7686	5 23	1 5544	5 66	1 7334
4 38	1 4770	4 81	1 7707	5 24	1 5563	5 67	1 7352
4 39	1 4793	4 82	1 7728	5 25	1 5582	5 68	1 7370
4 40	1 4816	4 83	1 7748	5 26	1 5601	5 69	1 7387
4 41	1 4839	4 84	1 7769	5 27	1 5620	5 70	1 7405
4 42	1 4861	4 85	1 7790	5 28	1 5639	5 71	1 7422
4 43	1 4884	4 86	1 7810	5 29	1 5658	5 72	1 7440
4 44	1 4907	4 87	1 7831	5 30	1 5677	5 73	1 7457
4 45	1 4929	4 88	1 7851	5 31	1 5696	5 74	1 7475
4 46	1 4951	4 89	1 7872	5 32	1 5715	5 75	1 7492
4 47	1 4974	4 90	1 7892	5 33	1 5734	5 76	1 7509
4 48	1 4996	4 91	1 7913	5 34	1 5752	5 77	1 7527
4 49	1 5019	4 92	1 7933	5 35	1 5771	5 78	1 7544
4 50	1 5041	4 93	1 7953	5 36	1 5790	5 79	1 7561
4 51	1 5063	4 94	1 7974	5 37	1 5808	5 80	1 7579
4 52	1 5085	4 95	1 7994	5 38	1 5827	5 81	1 7596
4 53	1 5107	4 96	1 6014	5 39	1 5845	5 82	1 7613
4 54	1 5129	4 97	1 6034	5 40	1 5864	5 83	1 7630
4 55	1 5151	4 98	1 6054	5 41	1 5882	5 84	1 7647
4 56	1 5173	4 99	1 6074	5 42	1 5901	5 85	1 7664
4 57	1 5195	5 00	1 6094	5 43	1 5919	5 86	1 7681
4 58	1 5217	5 01	1 6114	5 44	1 5938	5 87	1 7698
4 59	1 5239	5 02	1 6134	5 45	1 5956	5 88	1 7715
4 60	1 5261	5 03	1 6154	5 46	1 5974	5 89	1 7732
4 61	1 5283	5 04	1 6173	5 47	1 5993	5 90	1 7750
4 62	1 5304	5 05	1 6194	5 48	1 6011	5 91	1 7767
4 63	1 5326	5 06	1 6214	5 49	1 6029	5 92	1 7784
4 64	1 5347	5 07	1 6233	5 50	1 6047	5 93	1 7801
4 65	1 5369	5 08	1 6253	5 51	1 6066	5 94	1 7818
4 66	1 5390	5 09	1 6273	5 52	1 6084	5 95	1 7835
4 67	1 5412	5 10	1 6292	5 53	1 6102	5 96	1 7852
4 68	1 5433	5 11	1 6313	5 54	1 6120	5 97	1 7869
4 69	1 5455	5 12	1 6333	5 55	1 6138	5 98	1 7886
4 70	1 5476	5 13	1 6351	5 56	1 6156	5 99	1 7903
4 71	1 5497	5 14	1 6371	5 57	1 6174	6 00	1 7918
4 72	1 5518	5 15	1 6390	5 58	1 6192	6 01	1 7934
4 73	1 5539	5 16	1 6409	5 59	1 6210	6 02	1 7950
4 74	1 5560	5 17	1 6429	5 60	1 6228	6 03	1 7967
4 75	1 5581	5 18	1 6448	5 61	1 6246	6 04	1 7983
4 76	1 5602	5 19	1 6467	5 62	1 6263	6 05	1 8000
4 77	1 5623	5 20	1 6487	5 63	1 6281	6 06	1 8016
4 78	1 5644	5 21	1 6506	5 64	1 6299	6 07	1 8032
4 79	1 5665	5 22	1 6525	5 65	1 6317	6 08	1 8048

No	Log.	No	Log	No	Log	No	Log.
6-09	1.8066	6-52	1.8749	6-95	1.9387	7-38	1.9988
6-10	1.8083	6-53	1.8764	6-96	1.9402	7-39	2.0001
6-11	1.8099	6-54	1.8779	6-97	1.9416	7-40	2.0015
6-12	1.8116	6-55	1.8795	6-98	1.9430	7-41	2.0028
6-13	1.8132	6-56	1.8810	6-99	1.9445	7-42	2.0042
6-14	1.8148	6-57	1.8825	7-00	1.9459	7-43	2.0055
6-15	1.8165	6-58	1.8840	7-01	1.9473	7-44	2.0069
6-16	1.8181	6-59	1.8856	7-02	1.9488	7-45	2.0082
6-17	1.8197	6-60	1.8871	7-03	1.9502	7-46	2.0096
6-18	1.8213	6-61	1.8886	7-04	1.9516	7-47	2.0109
6-19	1.8229	6-62	1.8901	7-05	1.9530	7-48	2.0122
6-20	1.8245	6-63	1.8916	7-06	1.9544	7-49	2.0136
6-21	1.8262	6-64	1.8931	7-07	1.9559	7-50	2.0149
6-22	1.8278	6-65	1.8946	7-08	1.9573	7-51	2.0162
6-23	1.8294	6-66	1.8961	7-09	1.9587	7-52	2.0176
6-24	1.8310	6-67	1.8976	7-10	1.9601	7-53	2.0189
6-25	1.8326	6-68	1.8991	7-11	1.9615	7-54	2.0202
6-26	1.8342	6-69	1.9006	7-12	1.9629	7-55	2.0215
6-27	1.8358	6-70	1.9021	7-13	1.9643	7-56	2.0229
6-28	1.8374	6-71	1.9036	7-14	1.9657	7-57	2.0242
6-29	1.8390	6-72	1.9051	7-15	1.9671	7-58	2.0255
6-30	1.8405	6-73	1.9066	7-16	1.9685	7-59	2.0268
6-31	1.8421	6-74	1.9081	7-17	1.9699	7-60	2.0281
6-32	1.8437	6-75	1.9095	7-18	1.9713	7-61	2.0295
6-33	1.8453	6-76	1.9110	7-19	1.9727	7-62	2.0308
6-34	1.8469	6-77	1.9125	7-20	1.9741	7-63	2.0321
6-35	1.8485	6-78	1.9140	7-21	1.9755	7-64	2.0334
6-36	1.8500	6-79	1.9155	7-22	1.9769	7-65	2.0347
6-37	1.8516	6-80	1.9169	7-23	1.9782	7-66	2.0360
6-38	1.8532	6-81	1.9184	7-24	1.9796	7-67	2.0373
6-39	1.8547	6-82	1.9198	7-25	1.9810	7-68	2.0386
6-40	1.8563	6-83	1.9213	7-26	1.9824	7-69	2.0399
6-41	1.8579	6-84	1.9228	7-27	1.9838	7-70	2.0412
6-42	1.8594	6-85	1.9242	7-28	1.9851	7-71	2.0425
6-43	1.8610	6-86	1.9257	7-29	1.9865	7-72	2.0438
6-44	1.8625	6-87	1.9272	7-30	1.9879	7-73	2.0451
6-45	1.8641	6-88	1.9286	7-31	1.9892	7-74	2.0464
6-46	1.8656	6-89	1.9301	7-32	1.9906	7-75	2.0477
6-47	1.8672	6-90	1.9315	7-33	1.9920	7-76	2.0490
6-48	1.8687	6-91	1.9330	7-34	1.9933	7-77	2.0503
6-49	1.8703	6-92	1.9344	7-35	1.9947	7-78	2.0516
6-50	1.8718	6-93	1.9359	7-36	1.9961	7-79	2.0528
6-51	1.8733	6-94	1.9373	7-37	1.9975	7-80	2.0541

No	Log	No	Log	No	Log	No	Log
7.81	2.0574	8.24	2.1090	8.67	2.1599	9.10	2.2083
7.82	2.0567	8.25	2.1102	8.68	2.1610	9.11	2.2094
7.83	2.0560	8.26	2.1114	8.69	2.1622	9.12	2.2105
7.84	2.0552	8.27	2.1126	8.70	2.1633	9.13	2.2116
7.85	2.0603	8.28	2.1138	8.71	2.1645	9.14	2.2127
7.86	2.0614	8.29	2.1150	8.72	2.1656	9.15	2.2138
7.87	2.0626	8.30	2.1163	8.73	2.1668	9.16	2.2149
7.88	2.0638	8.31	2.1175	8.74	2.1679	9.17	2.2159
7.89	2.0650	8.32	2.1187	8.75	2.1691	9.18	2.2170
7.90	2.0662	8.33	2.1199	8.76	2.1702	9.19	2.2181
7.91	2.0674	8.34	2.1211	8.77	2.1713	9.20	2.2192
7.92	2.0686	8.35	2.1223	8.78	2.1725	9.21	2.2203
7.93	2.0697	8.36	2.1235	8.79	2.1736	9.22	2.2214
7.94	2.0710	8.37	2.1247	8.80	2.1748	9.23	2.2225
7.95	2.0732	8.38	2.1258	8.81	2.1759	9.24	2.2236
7.96	2.0744	8.39	2.1270	8.82	2.1770	9.25	2.2247
7.97	2.0757	8.40	2.1282	8.83	2.1782	9.26	2.2258
7.98	2.0769	8.41	2.1294	8.84	2.1793	9.27	2.2269
7.99	2.0782	8.42	2.1306	8.85	2.1804	9.28	2.2279
8.00	2.0794	8.43	2.1318	8.86	2.1815	9.29	2.2289
8.01	2.0807	8.44	2.1330	8.87	2.1827	9.30	2.2300
8.02	2.0819	8.45	2.1342	8.88	2.1838	9.31	2.2311
8.03	2.0832	8.46	2.1353	8.89	2.1849	9.32	2.2322
8.04	2.0844	8.47	2.1365	8.90	2.1861	9.33	2.2333
8.05	2.0857	8.48	2.1377	8.91	2.1872	9.34	2.2344
8.06	2.0869	8.49	2.1389	8.92	2.1883	9.35	2.2355
8.07	2.0882	8.50	2.1401	8.93	2.1894	9.36	2.2366
8.08	2.0894	8.51	2.1412	8.94	2.1905	9.37	2.2377
8.09	2.0907	8.52	2.1424	8.95	2.1917	9.38	2.2388
8.10	2.0919	8.53	2.1436	8.96	2.1928	9.39	2.2399
8.11	2.0931	8.54	2.1448	8.97	2.1939	9.40	2.2410
8.12	2.0943	8.55	2.1459	8.98	2.1950	9.41	2.2421
8.13	2.0956	8.56	2.1471	8.99	2.1961	9.42	2.2432
8.14	2.0968	8.57	2.1483	9.00	2.1972	9.43	2.2443
8.15	2.0980	8.58	2.1494	9.01	2.1983	9.44	2.2454
8.16	2.0992	8.59	2.1506	9.02	2.1994	9.45	2.2465
8.17	2.1005	8.60	2.1518	9.03	2.2006	9.46	2.2476
8.18	2.1017	8.61	2.1529	9.04	2.2017	9.47	2.2487
8.19	2.1029	8.62	2.1541	9.05	2.2028	9.48	2.2498
8.20	2.1041	8.63	2.1552	9.06	2.2039	9.49	2.2509
8.21	2.1054	8.64	2.1564	9.07	2.2050	9.50	2.2520
8.22	2.1066	8.65	2.1576	9.08	2.2061	9.51	2.2531
8.23	2.1078	8.66	2.1587	9.09	2.2072	9.52	2.2542

No.	Log.	No.	Log.	No.	Log.	No.	Log.
9-53	2-2544	9-73	2-2752	9-93	2-2956	13-25	2-5840
9-54	2-2555	9-74	2-2762	9-94	2-2966	13-50	2-6027
9-55	2-2565	9-75	2-2773	9-95	2-2976	13-75	2-6211
9-56	2-2576	9-76	2-2783	9-96	2-2986	14-00	2-6391
9-57	2-2586	9-77	2-2793	9-97	2-2996	14-25	2-6567
9-58	2-2597	9-78	2-2803	9-98	2-3006	14-50	2-6740
9-59	2-2607	9-79	2-2814	9-99	2-3016	14-75	2-6913
9-60	2-2618	9-80	2-2824	10-00	2-3026	15-00	2-7081
9-61	2-2628	9-81	2-2834	10-25	2-3279	15-50	2-7408
9-62	2-2638	9-82	2-2844	10-50	2-3513	16-00	2-7726
9-63	2-2649	9-83	2-2854	10-75	2-3749	16-50	2-8034
9-64	2-2659	9-84	2-2865	11-00	2-3979	17-00	2-8332
9-65	2-2670	9-85	2-2875	11-25	2-4201	17-50	2-8621
9-66	2-2680	9-86	2-2885	11-50	2-4430	18-00	2-8904
9-67	2-2690	9-87	2-2895	11-75	2-4636	18-50	2-9173
9-68	2-2701	9-88	2-2905	12-00	2-4849	19-00	2-9444
9-69	2-2711	9-89	2-2915	12-25	2-5052	19-50	2-9703
9-70	2-2721	9-90	2-2925	12-50	2-5262	20-00	2-9957
9-71	2-2732	9-91	2-2935	12-75	2-5455		
9-72	2-2742	9-92	2-2946	13-00	2-5649		

TABLE 6.—SINES AND COSINES OF ANGLES FROM
0° TO 90°.*

(RADIUS = 1.)

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
0	90	·00000	5-5	84-5	·09585
0-5	89-5	·00873	6	84	·10453
1	89	·01745	6-5	83-5	·11320
1-5	88-5	·02618	7	83	·12187
2	88	·03490	7-5	82-5	·13053
2-5	87-5	·04362	8	82	·13917
3	87	·05234	8-5	81-5	·14781
3-5	86-5	·06105	9	81	·15643
4	86	·06976	9-5	80-5	·16505
4-5	85-5	·07846	10	80	·17365
5	85	·08716	10-5	79-5	·18224

* See Introduction, ante, p. 6.

N	0	1	2	3	4	5	6	7	8	9	D
911	979718	979765	979811	979857	979903	979949	979995	980041	980087	980133	48
912	979765	979811	979857	979903	979949	979995	980041	980087	980133	980179	48
913	979811	979857	979903	979949	979995	980041	980087	980133	980179	980225	48
914	979857	979903	979949	979995	980041	980087	980133	980179	980225	980271	47
915	979903	979949	979995	980041	980087	980133	980179	980225	980271	980317	47
916	979949	979995	980041	980087	980133	980179	980225	980271	980317	980363	47
917	979995	980041	980087	980133	980179	980225	980271	980317	980363	980409	47
918	980041	980087	980133	980179	980225	980271	980317	980363	980409	980455	47
919	980087	980133	980179	980225	980271	980317	980363	980409	980455	980501	47
920	980133	980179	980225	980271	980317	980363	980409	980455	980501	980547	47
921	980179	980225	980271	980317	980363	980409	980455	980501	980547	980593	47
922	980225	980271	980317	980363	980409	980455	980501	980547	980593	980639	47
923	980271	980317	980363	980409	980455	980501	980547	980593	980639	980685	47
924	980317	980363	980409	980455	980501	980547	980593	980639	980685	980731	47
925	980363	980409	980455	980501	980547	980593	980639	980685	980731	980777	47
926	980409	980455	980501	980547	980593	980639	980685	980731	980777	980823	47
927	980455	980501	980547	980593	980639	980685	980731	980777	980823	980869	47
928	980501	980547	980593	980639	980685	980731	980777	980823	980869	980915	47
929	980547	980593	980639	980685	980731	980777	980823	980869	980915	980961	47
930	980593	980639	980685	980731	980777	980823	980869	980915	980961	981007	47
931	980639	980685	980731	980777	980823	980869	980915	980961	981007	981053	47
932	980685	980731	980777	980823	980869	980915	980961	981007	981053	981099	47
933	980731	980777	980823	980869	980915	980961	981007	981053	981099	981145	47
934	980777	980823	980869	980915	980961	981007	981053	981099	981145	981191	46
935	980823	980869	980915	980961	981007	981053	981099	981145	981191	981237	46

N.	0	1	2	3	4	5	6	7	8	9	D.
936	971276	971822	971369	971415	971461	971508	971551	971601	971647	971693	46
937	971740	971786	971832	971879	971925	971971	972018	972064	972110	972157	46
938	972203	972249	972295	972342	972388	972434	972481	972527	972573	972619	46
939	972666	972712	972758	972804	972851	972897	972943	972989	973035	973082	46
940	973128	973174	973220	973266	973313	973359	973405	973451	973497	973543	46
941	973590	973636	973682	973728	973774	973820	973866	973913	973959	974005	46
942	974051	974097	974143	974189	974235	974281	974327	974374	974420	974466	46
943	974512	974558	974604	974650	974696	974742	974788	974834	974880	974926	46
944	974972	975018	975064	975110	975156	975202	975248	975294	975340	975386	46
945	975432	975478	975524	975570	975616	975662	975707	975753	975799	975845	46
946	975891	975937	975983	976029	976075	976121	976167	976212	976258	976304	46
947	976350	976396	976442	976488	976533	976579	976625	976671	976717	976763	46
948	976808	976854	976900	976946	976992	977037	977083	977129	977175	977220	46
949	977266	977312	977358	977403	977449	977495	977541	977586	977632	977678	46
950	977724	977769	977815	977861	977906	977952	977998	978043	978089	978135	46
951	978181	978226	978272	978317	978363	978409	978454	978500	978546	978591	46
952	978637	978683	978728	978774	978819	978865	978911	978957	979002	979047	46
953	979093	979138	979184	979230	979275	979321	979366	979412	979457	979503	46
954	979548	979594	979639	979685	979730	979777	979821	979867	979912	979958	46
955	980003	980049	980094	980140	980185	980231	980276	980322	980367	980412	45
956	980458	980503	980549	980594	980640	980685	980730	980776	980821	980867	45
957	980912	980957	981003	981048	981093	981139	981184	981229	981275	981320	45
958	981366	981411	981456	981501	981547	981592	981637	981683	981728	981773	45
959	981819	981864	981909	981954	982000	982045	982091	982135	982181	982226	45
960	982271	982316	982362	982407	982452	982497	982543	982588	982633	982678	45

N	0	1	2	3	4	5	6	7	8	9	
911	0.99518	0.99526	0.99534	0.99541	0.99549	0.99557	0.99564	0.99572	0.99580	0.99587	48
912	0.99999	0.99992	0.99985	0.99978	0.99971	0.99964	0.99957	0.99950	0.99943	0.99936	48
913	0.00471	0.00464	0.00457	0.00450	0.00443	0.00436	0.00429	0.00422	0.00415	0.00408	48
914	0.00914	0.00907	0.00900	0.00893	0.00886	0.00879	0.00872	0.00865	0.00858	0.00851	47
915	0.01421	0.01414	0.01407	0.01400	0.01393	0.01386	0.01379	0.01372	0.01365	0.01358	47
916	0.01925	0.01918	0.01911	0.01904	0.01897	0.01890	0.01883	0.01876	0.01869	0.01862	47
917	0.02430	0.02423	0.02416	0.02409	0.02402	0.02395	0.02388	0.02381	0.02374	0.02367	47
918	0.02934	0.02927	0.02920	0.02913	0.02906	0.02899	0.02892	0.02885	0.02878	0.02871	47
919	0.03438	0.03431	0.03424	0.03417	0.03410	0.03403	0.03396	0.03389	0.03382	0.03375	47
920	0.03942	0.03935	0.03928	0.03921	0.03914	0.03907	0.03900	0.03893	0.03886	0.03879	47
921	0.04446	0.04439	0.04432	0.04425	0.04418	0.04411	0.04404	0.04397	0.04390	0.04383	47
922	0.04950	0.04943	0.04936	0.04929	0.04922	0.04915	0.04908	0.04901	0.04894	0.04887	47
923	0.05454	0.05447	0.05440	0.05433	0.05426	0.05419	0.05412	0.05405	0.05398	0.05391	47
924	0.05958	0.05951	0.05944	0.05937	0.05930	0.05923	0.05916	0.05909	0.05902	0.05895	47
925	0.06462	0.06455	0.06448	0.06441	0.06434	0.06427	0.06420	0.06413	0.06406	0.06399	47
926	0.06966	0.06959	0.06952	0.06945	0.06938	0.06931	0.06924	0.06917	0.06910	0.06903	47
927	0.07470	0.07463	0.07456	0.07449	0.07442	0.07435	0.07428	0.07421	0.07414	0.07407	47
928	0.07974	0.07967	0.07960	0.07953	0.07946	0.07939	0.07932	0.07925	0.07918	0.07911	47
929	0.08478	0.08471	0.08464	0.08457	0.08450	0.08443	0.08436	0.08429	0.08422	0.08415	47
930	0.08982	0.08975	0.08968	0.08961	0.08954	0.08947	0.08940	0.08933	0.08926	0.08919	47
931	0.09486	0.09479	0.09472	0.09465	0.09458	0.09451	0.09444	0.09437	0.09430	0.09423	47
932	0.09990	0.09983	0.09976	0.09969	0.09962	0.09955	0.09948	0.09941	0.09934	0.09927	47
933	0.10494	0.10487	0.10480	0.10473	0.10466	0.10459	0.10452	0.10445	0.10438	0.10431	47
934	0.10998	0.10991	0.10984	0.10977	0.10970	0.10963	0.10956	0.10949	0.10942	0.10935	46
935	0.11502	0.11495	0.11488	0.11481	0.11474	0.11467	0.11460	0.11453	0.11446	0.11439	46

N.	0	1	2	3	4	5	6	7	8	9	D
936	971276	971822	971369	971415	971461	971508	971554	971601	971647	971693	46
937	971740	971786	971832	971879	971925	971971	972018	972064	972110	972157	46
938	972203	972249	972295	972342	972388	972434	972481	972527	972573	972619	46
939	972666	972712	972758	972804	972851	972897	972943	972989	973035	973082	46
940	973128	973174	973220	973266	973313	973359	973405	973451	973497	973543	46
941	973589	973636	973682	973728	973774	973820	973866	973912	973958	974005	46
942	974051	974097	974143	974189	974235	974281	974327	974374	974420	974466	46
943	974512	974558	974604	974650	974696	974742	974788	974834	974880	974926	46
944	974972	975018	975064	975110	975156	975202	975248	975294	975340	975386	46
945	975432	975478	975524	975570	975616	975662	975707	975753	975799	975845	46
946	975891	975937	975983	976029	976075	976121	976167	976212	976258	976304	46
947	976350	976396	976442	976488	976534	976580	976625	976671	976717	976763	46
948	976808	976854	976900	976946	976992	977037	977083	977129	977175	977221	46
949	977266	977312	977358	977404	977450	977496	977541	977587	977632	977678	46
950	977724	977769	977815	977861	977907	977952	977998	978043	978089	978135	46
951	978181	978226	978272	978318	978363	978409	978455	978500	978546	978591	46
952	978637	978683	978729	978774	978820	978866	978911	978957	979002	979047	46
953	979093	979138	979184	979230	979275	979321	979366	979412	979457	979503	46
954	979548	979594	979639	979685	979730	979776	979821	979867	979912	979958	46
955	980003	980049	980094	980140	980185	980231	980276	980322	980367	980412	45
956	980458	980503	980549	980594	980639	980685	980730	980776	980821	980867	45
957	980912	980957	981003	981048	981093	981139	981184	981230	981275	981320	45
958	981366	981411	981456	981501	981547	981592	981637	981683	981728	981773	45
959	981819	981864	981909	981954	982000	982045	982090	982135	982181	982226	45
960	982271	982316	982362	982407	982452	982497	982543	982588	982633	982678	45

D	P	X	Z	9	5	4	3	2	1	0
45	981580	981580	1474966	1028606	2493606	4110606	5094606	4759306	1084606	981580
46	981680	981680	1475066	1028666	2493666	4110666	5094666	4759366	1084666	981680
47	981780	981780	1475166	1028726	2493726	4110726	5094726	4759426	1084726	981780
48	981880	981880	1475266	1028786	2493786	4110786	5094786	4759486	1084786	981880
49	981980	981980	1475366	1028846	2493846	4110846	5094846	4759546	1084846	981980
50	982080	982080	1475466	1028906	2493906	4110906	5094906	4759606	1084906	982080
51	982180	982180	1475566	1028966	2493966	4110966	5094966	4759666	1084966	982180
52	982280	982280	1475666	1029026	2494026	4111026	5095026	4759726	1085026	982280
53	982380	982380	1475766	1029086	2494086	4111086	5095086	4759786	1085086	982380
54	982480	982480	1475866	1029146	2494146	4111146	5095146	4759846	1085146	982480
55	982580	982580	1475966	1029206	2494206	4111206	5095206	4759906	1085206	982580
56	982680	982680	1476066	1029266	2494266	4111266	5095266	4759966	1085266	982680
57	982780	982780	1476166	1029326	2494326	4111326	5095326	4760026	1085326	982780
58	982880	982880	1476266	1029386	2494386	4111386	5095386	4760086	1085386	982880
59	982980	982980	1476366	1029446	2494446	4111446	5095446	4760146	1085446	982980
60	983080	983080	1476466	1029506	2494506	4111506	5095506	4760206	1085506	983080
61	983180	983180	1476566	1029566	2494566	4111566	5095566	4760266	1085566	983180
62	983280	983280	1476666	1029626	2494626	4111626	5095626	4760326	1085626	983280
63	983380	983380	1476766	1029686	2494686	4111686	5095686	4760386	1085686	983380
64	983480	983480	1476866	1029746	2494746	4111746	5095746	4760446	1085746	983480
65	983580	983580	1476966	1029806	2494806	4111806	5095806	4760506	1085806	983580
66	983680	983680	1477066	1029866	2494866	4111866	5095866	4760566	1085866	983680
67	983780	983780	1477166	1029926	2494926	4111926	5095926	4760626	1085926	983780
68	983880	983880	1477266	1029986	2494986	4111986	5095986	4760686	1085986	983880
69	983980	983980	1477366	1030046	2495046	4112046	5096046	4760746	1086046	983980
70	984080	984080	1477466	1030106	2495106	4112106	5096106	4760806	1086106	984080

N.	0	1	2	3	4	5	6	7	8	9	D.
986	993877	993921	993965	994009	994053	994097	994141	994185	994229	994273	44
987	994317	994361	994405	994449	994493	994537	994581	994625	994669	994713	44
988	994757	994801	994845	994889	994933	994977	995021	995065	995109	995153	44
989	995196	995240	995284	995328	995372	995416	995460	995504	995548	995592	44
990	995636	995680	995724	995768	995812	995856	995900	995944	995988	996032	44
991	996074	996117	996161	996205	996249	996293	996337	996381	996425	996469	44
992	996512	996556	996600	996644	996688	996732	996776	996820	996864	996908	44
993	996949	996993	997037	997081	997125	997169	997213	997257	997301	997345	44
994	997389	997433	997477	997521	997565	997609	997653	997697	997741	997785	44
995	997829	997873	997917	997961	998005	998049	998093	998137	998181	998225	44
996	998269	998313	998357	998401	998445	998489	998533	998577	998621	998665	44
997	998709	998753	998797	998841	998885	998929	998973	999017	999061	999105	44
998	999149	999193	999237	999281	999325	999369	999413	999457	999501	999545	44
999	999589	999633	999677	999721	999765	999809	999853	999897	999941	999985	48

TABLE 5. HYPERBOLIC LOGARITHMS OF NUMBERS
FROM 1.01 TO 20.*

N	Log	N	Log	N	Log	N	Log
1.01	.0099	1.42	.3507	1.83	.6043	2.24	.8065
1.02	.0198	1.43	.3577	1.84	.6098	2.25	.8139
1.03	.0296	1.44	.3646	1.85	.6152	2.26	.8194
1.04	.0392	1.45	.3716	1.86	.6206	2.27	.8248
1.05	.0488	1.46	.3784	1.87	.6259	2.28	.8298
1.06	.0583	1.47	.3853	1.88	.6313	2.29	.8346
1.07	.0677	1.48	.392	1.89	.6366	2.30	.8392
1.08	.0770	1.49	.3988	1.90	.6419	2.31	.8437
1.09	.0862	1.50	.4055	1.91	.6471	2.32	.8481
1.10	.0953	1.51	.4121	1.92	.6523	2.33	.8524
1.11	.1044	1.52	.4187	1.93	.6575	2.34	.8566
1.12	.1133	1.53	.4253	1.94	.6627	2.35	.8607
1.13	.1222	1.54	.4318	1.95	.6678	2.36	.8648
1.14	.1310	1.55	.4383	1.96	.6729	2.37	.8688
1.15	.1398	1.56	.4447	1.97	.6780	2.38	.8728
1.16	.1484	1.57	.4511	1.98	.6831	2.39	.8767
1.17	.1570	1.58	.4574	1.99	.6881	2.40	.8806
1.18	.1657	1.59	.4637	2.00	.6931	2.41	.8844
1.19	.1740	1.60	.4700	2.01	.6981	2.42	.8882
1.20	.1823	1.61	.4762	2.02	.7031	2.43	.8919
1.21	.1905	1.62	.4824	2.03	.7080	2.44	.8956
1.22	.1988	1.63	.4886	2.04	.7129	2.45	.8992
1.23	.2070	1.64	.4947	2.05	.7178	2.46	.9028
1.24	.2151	1.65	.5008	2.06	.7227	2.47	.9063
1.25	.2231	1.66	.5068	2.07	.7275	2.48	.9098
1.26	.2311	1.67	.5128	2.08	.7324	2.49	.9132
1.27	.2390	1.68	.5188	2.09	.7372	2.50	.9166
1.28	.2469	1.69	.5247	2.10	.7419	2.51	.9200
1.29	.2547	1.70	.5306	2.11	.7467	2.52	.9233
1.30	.2624	1.71	.5365	2.12	.7514	2.53	.9266
1.31	.2701	1.72	.5423	2.13	.7561	2.54	.9298
1.32	.2776	1.73	.5481	2.14	.7608	2.55	.9330
1.33	.2852	1.74	.5539	2.15	.7655	2.56	.9361
1.34	.2927	1.75	.5596	2.16	.7701	2.57	.9392
1.35	.3001	1.76	.5653	2.17	.7747	2.58	.9423
1.36	.3075	1.77	.5710	2.18	.7793	2.59	.9453
1.37	.3148	1.78	.5766	2.19	.7839	2.60	.9483
1.38	.3221	1.79	.5822	2.20	.7885	2.61	.9513
1.39	.3293	1.80	.5878	2.21	.7931	2.62	.9542
1.40	.3365	1.81	.5934	2.22	.7977	2.63	.9571
1.41	.3436	1.82	.5988	2.23	.8020	2.64	.9600

* See Introduction, note, p. 9.

N	Log	N	Log	N	Log	N	Log
2 65	9746	3 08	1 1249	3 51	1 2556	3 94	1 3712
2 66	9783	3 09	1 1282	3 52	1 2585	3 95	1 3737
2 67	9821	3 10	1 1314	3 53	1 2613	3 96	1 3762
2 68	9858	3 11	1 1346	3 54	1 2641	3 97	1 3788
2 69	9895	3 12	1 1378	3 55	1 2669	3 98	1 3813
2 70	9933	3 13	1 1410	3 56	1 2698	3 99	1 3838
2 71	9969	3 14	1 1442	3 57	1 2726	4 00	1 3863
2 72	1 0006	3 15	1 1474	3 58	1 2754	4 01	1 3888
2 73	1 0043	3 16	1 1506	3 59	1 2782	4 02	1 3913
2 74	1 0080	3 17	1 1537	3 60	1 2809	4 03	1 3938
2 75	1 0116	3 18	1 1569	3 61	1 2837	4 04	1 3962
2 76	1 0152	3 19	1 1600	3 62	1 2865	4 05	1 3987
2 77	1 0188	3 20	1 1632	3 63	1 2892	4 06	1 4012
2 78	1 0225	3 21	1 1663	3 64	1 2920	4 07	1 4036
2 79	1 0260	3 22	1 1694	3 65	1 2947	4 08	1 4061
2 80	1 0296	3 23	1 1725	3 66	1 2975	4 09	1 4085
2 81	1 0332	3 24	1 1756	3 67	1 3002	4 10	1 4110
2 82	1 0367	3 25	1 1787	3 68	1 3029	4 11	1 4134
2 83	1 0403	3 26	1 1817	3 69	1 3056	4 12	1 4159
2 84	1 0438	3 27	1 1848	3 70	1 3083	4 13	1 4183
2 85	1 0473	3 28	1 1878	3 71	1 3110	4 14	1 4207
2 86	1 0508	3 29	1 1909	3 72	1 3137	4 15	1 4231
2 87	1 0543	3 30	1 1939	3 73	1 3164	4 16	1 4255
2 88	1 0578	3 31	1 1969	3 74	1 3191	4 17	1 4279
2 89	1 0614	3 32	1 1999	3 75	1 3218	4 18	1 4303
2 90	1 0647	3 33	1 2030	3 76	1 3244	4 19	1 4327
2 91	1 0682	3 34	1 2060	3 77	1 3271	4 20	1 4351
2 92	1 0716	3 35	1 2090	3 78	1 3297	4 21	1 4375
2 93	1 0750	3 36	1 2119	3 79	1 3324	4 22	1 4398
2 94	1 0784	3 37	1 2149	3 80	1 3350	4 23	1 4422
2 95	1 0818	3 38	1 2179	3 81	1 3376	4 24	1 4446
2 96	1 0852	3 39	1 2208	3 82	1 3403	4 25	1 4469
2 97	1 0886	3 40	1 2238	3 83	1 3429	4 26	1 4493
2 98	1 0919	3 41	1 2267	3 84	1 3455	4 27	1 4516
2 99	1 0953	3 42	1 2296	3 85	1 3481	4 28	1 4540
3 00	1 0986	3 43	1 2326	3 86	1 3507	4 29	1 4563
3 01	1 1019	3 44	1 2355	3 87	1 3533	4 30	1 4587
3 02	1 1053	3 45	1 2384	3 88	1 3558	4 31	1 4610
3 03	1 1086	3 46	1 2413	3 89	1 3584	4 32	1 4634
3 04	1 1119	3 47	1 2442	3 90	1 3610	4 33	1 4657
3 05	1 1151	3 48	1 2470	3 91	1 3635	4 34	1 4679
3 06	1 1184	3 49	1 2499	3 92	1 3661	4 35	1 4702
3 07	1 1217	3 50	1 2528	3 93	1 3686	4 36	1 4725

No.	Log.	No.	Log.	No.	Log.	No.	Log.
4.37	1.1748	4.80	1.6686	5.23	1.6544	5.66	1.7394
4.38	1.1770	4.81	1.6707	5.24	1.6563	5.67	1.7352
4.39	1.1793	4.82	1.6728	5.25	1.6583	5.68	1.7370
4.40	1.1816	4.83	1.6748	5.26	1.6601	5.69	1.7387
4.41	1.1839	4.84	1.6769	5.27	1.6620	5.70	1.7405
4.42	1.1861	4.85	1.6790	5.28	1.6639	5.71	1.7423
4.43	1.1884	4.86	1.6811	5.29	1.6658	5.72	1.7440
4.44	1.1907	4.87	1.6831	5.30	1.6677	5.73	1.7457
4.45	1.1929	4.88	1.6851	5.31	1.6696	5.74	1.7475
4.46	1.1951	4.89	1.6872	5.32	1.6714	5.75	1.7493
4.47	1.1974	4.90	1.6892	5.33	1.6734	5.76	1.7509
4.48	1.1996	4.91	1.6913	5.34	1.6752	5.77	1.7527
4.49	1.2019	4.92	1.6933	5.35	1.6771	5.78	1.7544
4.50	1.2041	4.93	1.6953	5.36	1.6790	5.79	1.7561
4.51	1.2063	4.94	1.6974	5.37	1.6808	5.80	1.7579
4.52	1.2085	4.95	1.6994	5.38	1.6827	5.81	1.7596
4.53	1.2107	4.96	1.7014	5.39	1.6845	5.82	1.7613
4.54	1.2129	4.97	1.7034	5.40	1.6864	5.83	1.7630
4.55	1.2151	4.98	1.7054	5.41	1.6883	5.84	1.7647
4.56	1.2173	4.99	1.7074	5.42	1.6901	5.85	1.7664
4.57	1.2195	5.00	1.7094	5.43	1.6919	5.86	1.7681
4.58	1.2217	5.01	1.7114	5.44	1.6938	5.87	1.7699
4.59	1.2239	5.02	1.7134	5.45	1.6956	5.88	1.7716
4.60	1.2261	5.03	1.7154	5.46	1.6974	5.89	1.7733
4.61	1.2282	5.04	1.7174	5.47	1.6993	5.90	1.7750
4.62	1.2304	5.05	1.7194	5.48	1.7011	5.91	1.7767
4.63	1.2326	5.06	1.7214	5.49	1.7029	5.92	1.7784
4.64	1.2347	5.07	1.7234	5.50	1.7047	5.93	1.7801
4.65	1.2369	5.08	1.7253	5.51	1.7066	5.94	1.7817
4.66	1.2390	5.09	1.7273	5.52	1.7084	5.95	1.7834
4.67	1.2412	5.10	1.7292	5.53	1.7102	5.96	1.7851
4.68	1.2433	5.11	1.7312	5.54	1.7120	5.97	1.7867
4.69	1.2454	5.12	1.7332	5.55	1.7138	5.98	1.7884
4.70	1.2476	5.13	1.7351	5.56	1.7156	5.99	1.7901
4.71	1.2497	5.14	1.7371	5.57	1.7174	6.00	1.7918
4.72	1.2518	5.15	1.7390	5.58	1.7192	6.01	1.7934
4.73	1.2539	5.16	1.7409	5.59	1.7210	6.02	1.7951
4.74	1.2560	5.17	1.7429	5.60	1.7228	6.03	1.7967
4.75	1.2581	5.18	1.7448	5.61	1.7246	6.04	1.7984
4.76	1.2602	5.19	1.7467	5.62	1.7263	6.05	1.8001
4.77	1.2623	5.20	1.7487	5.63	1.7281	6.06	1.8018
4.78	1.2644	5.21	1.7506	5.64	1.7299	6.07	1.8034
4.79	1.2665	5.22	1.7525	5.65	1.7317	6.08	1.8051

HYPERBOLIC LOGARITHMS.

8

No.	Log.	No.	Log.	No.	Log.	No.	Log.
6-09	1.8056	6-52	1.8749	6-85	1.9387	7-38	1.9988
6-10	1.8063	6-53	1.8754	6-86	1.9402	7-39	2.0001
6-11	1.8069	6-54	1.8759	6-87	1.9416	7-40	2.0015
6-12	1.8116	6-55	1.8795	6-88	1.9430	7-41	2.0028
6-13	1.8132	6-56	1.8810	6-89	1.9445	7-42	2.0042
6-14	1.8148	6-57	1.8825	7-00	1.9459	7-43	2.0055
6-15	1.8165	6-58	1.8840	7-01	1.9473	7-44	2.0069
6-16	1.8181	6-59	1.8856	7-02	1.9488	7-45	2.0082
6-17	1.8197	6-60	1.8871	7-03	1.9502	7-46	2.0096
6-18	1.8213	6-61	1.8886	7-04	1.9516	7-47	2.0109
6-19	1.8229	6-62	1.8901	7-05	1.9530	7-48	2.0122
6-20	1.8245	6-63	1.8916	7-06	1.9544	7-49	2.0136
6-21	1.8262	6-64	1.8931	7-07	1.9559	7-50	2.0149
6-22	1.8278	6-65	1.8946	7-08	1.9573	7-51	2.0162
6-23	1.8294	6-66	1.8961	7-09	1.9587	7-52	2.0176
6-24	1.8310	6-67	1.8976	7-10	1.9601	7-53	2.0189
6-25	1.8326	6-68	1.8991	7-11	1.9615	7-54	2.0202
6-26	1.8342	6-69	1.9006	7-12	1.9629	7-55	2.0215
6-27	1.8358	6-70	1.9021	7-13	1.9643	7-56	2.0228
6-28	1.8374	6-71	1.9036	7-14	1.9657	7-57	2.0242
6-29	1.8390	6-72	1.9051	7-15	1.9671	7-58	2.0255
6-30	1.8405	6-73	1.9066	7-16	1.9685	7-59	2.0268
6-31	1.8421	6-74	1.9081	7-17	1.9699	7-60	2.0281
6-32	1.8437	6-75	1.9095	7-18	1.9713	7-61	2.0295
6-33	1.8453	6-76	1.9110	7-19	1.9727	7-62	2.0308
6-34	1.8469	6-77	1.9125	7-20	1.9741	7-63	2.0321
6-35	1.8485	6-78	1.9140	7-21	1.9755	7-64	2.0334
6-36	1.8500	6-79	1.9155	7-22	1.9769	7-65	2.0347
6-37	1.8516	6-80	1.9169	7-23	1.9782	7-66	2.0360
6-38	1.8532	6-81	1.9184	7-24	1.9796	7-67	2.0373
6-39	1.8547	6-82	1.9199	7-25	1.9810	7-68	2.0386
6-40	1.8563	6-83	1.9213	7-26	1.9824	7-69	2.0399
6-41	1.8579	6-84	1.9228	7-27	1.9838	7-70	2.0412
6-42	1.8594	6-85	1.9242	7-28	1.9851	7-71	2.0425
6-43	1.8610	6-86	1.9257	7-29	1.9865	7-72	2.0438
6-44	1.8625	6-87	1.9272	7-30	1.9879	7-73	2.0451
6-45	1.8641	6-88	1.9286	7-31	1.9892	7-74	2.0464
6-46	1.8656	6-89	1.9301	7-32	1.9906	7-75	2.0477
6-47	1.8672	6-90	1.9315	7-33	1.9920	7-76	2.0490
6-48	1.8687	6-91	1.9330	7-34	1.9933	7-77	2.0503
6-49	1.8703	6-92	1.9344	7-35	1.9947	7-78	2.0516
6-50	1.8718	6-93	1.9359	7-36	1.9961	7-79	2.0528
6-51	1.8733	6-94	1.9373	7-37	1.9974	7-80	2.0541

No.	Log.	No.	Log.	No.	Log.	No.	Log.
781	2.0574	824	2.1099	867	2.1599	910	2.2083
782	2.0567	825	2.1102	868	2.1610	911	2.2094
783	2.0563	826	2.1114	869	2.1627	912	2.2105
784	2.0562	827	2.1126	870	2.1633	913	2.2116
785	2.0565	828	2.1138	871	2.1645	914	2.2127
786	2.0568	829	2.1154	872	2.1656	915	2.2138
787	2.0581	830	2.1163	873	2.1668	916	2.2148
788	2.0593	831	2.1175	874	2.1679	917	2.2159
789	2.0606	832	2.1187	875	2.1691	918	2.2170
790	2.0619	833	2.1199	876	2.1702	919	2.2181
791	2.0631	834	2.1211	877	2.1713	920	2.2192
792	2.0644	835	2.1223	878	2.1725	921	2.2203
793	2.0657	836	2.1235	879	2.1736	922	2.2214
794	2.0670	837	2.1247	880	2.1748	923	2.2225
795	2.0682	838	2.1258	881	2.1759	924	2.2236
796	2.0694	839	2.1270	882	2.1770	925	2.2247
797	2.0707	840	2.1282	883	2.1782	926	2.2257
798	2.0719	841	2.1294	884	2.1793	927	2.2268
799	2.0732	842	2.1306	885	2.1804	928	2.2279
800	2.0744	843	2.1318	886	2.1815	929	2.2289
801	2.0757	844	2.1330	887	2.1827	930	2.2300
802	2.0769	845	2.1342	888	2.1838	931	2.2311
803	2.0782	846	2.1353	889	2.1849	932	2.2322
804	2.0794	847	2.1365	890	2.1861	933	2.2333
805	2.0807	848	2.1377	891	2.1872	934	2.2344
806	2.0819	849	2.1389	892	2.1883	935	2.2354
807	2.0832	850	2.1401	893	2.1894	936	2.2365
808	2.0844	851	2.1412	894	2.1905	937	2.2376
809	2.0857	852	2.1424	895	2.1917	938	2.2386
810	2.0869	853	2.1436	896	2.1928	939	2.2397
811	2.0881	854	2.1448	897	2.1939	940	2.2407
812	2.0894	855	2.1459	898	2.1950	941	2.2418
813	2.0906	856	2.1471	899	2.1961	942	2.2428
814	2.0918	857	2.1483	900	2.1972	943	2.2439
815	2.0930	858	2.1494	901	2.1983	944	2.2450
816	2.0942	859	2.1506	902	2.1994	945	2.2460
817	2.0954	860	2.1518	903	2.2006	946	2.2471
818	2.0967	861	2.1529	904	2.2017	947	2.2481
819	2.0979	862	2.1541	905	2.2028	948	2.2492
820	2.1001	863	2.1552	906	2.2039	949	2.2502
821	2.1014	864	2.1564	907	2.2050	950	2.2513
822	2.1026	865	2.1576	908	2.2061	951	2.2523
823	2.1038	866	2.1587	909	2.2072	952	2.2534

No.	Log.	No.	Log.	No.	Log.	No.	Log.
9-53	2-2544	9-73	2-2752	9-93	2-2956	13-25	2-5840
9-54	2-2555	9-74	2-2762	9-94	2-2966	13-50	2-6027
9-55	2-2565	9-75	2-2773	9-95	2-2976	13-75	2-6211
9-56	2-2576	9-76	2-2783	9-96	2-2986	14-00	2-6391
9-57	2-2586	9-77	2-2793	9-97	2-2996	14-25	2-6567
9-58	2-2597	9-78	2-2803	9-98	2-3006	14-50	2-6740
9-59	2-2607	9-79	2-2814	9-99	2-3016	14-75	2-6913
9-60	2-2618	9-80	2-2824	10-00	2-3026	15-00	2-7081
9-61	2-2628	9-81	2-2834	10-25	2-3279	15-50	2-7408
9-62	2-2638	9-82	2-2844	10-50	2-3513	16-00	2-7726
9-63	2-2649	9-83	2-2854	10-75	2-3749	16-50	2-8034
9-64	2-2659	9-84	2-2865	11-00	2-3979	17-00	2-8332
9-65	2-2670	9-85	2-2875	11-25	2-4201	17-50	2-8621
9-66	2-2680	9-86	2-2885	11-50	2-4430	18-00	2-8904
9-67	2-2690	9-87	2-2895	11-75	2-4636	18-50	2-9173
9-68	2-2701	9-88	2-2905	12-00	2-4849	19-00	2-9444
9-69	2-2711	9-89	2-2915	12-25	2-5052	19-50	2-9703
9-70	2-2721	9-90	2-2925	12-50	2-5262	20-00	2-9957
9-71	2-2732	9-91	2-2935	12-75	2-5455		
9-72	2-2742	9-92	2-2946	13-00	2-5649		

TABLE 6.—SINES AND COSINES OF ANGLES FROM
0° TO 90°.*

(RADIUS = 1.)

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
0	90	·00000	5-5	84-5	·09585
0-5	89-5	·00873	6	84	·10453
1	89	·01745	6-5	83-5	·11320
1-5	88-5	·02618	7	83	·12187
2	88	·03490	7-5	82-5	·13053
2-5	87-5	·04362	8	82	·13917
3	87	·05234	8-5	81-5	·14781
3-5	86-5	·06105	9	81	·15643
4	86	·06976	9-5	80-5	·16505
4-5	85-5	·07846	10	80	·17365
5	85	·08716	10-5	79-5	·18224

* See Introduction, ante, p. 6.

Sines of Angles	Cosines of Angles.	Val. es.	Sines of Angles	Cosines of Angles	Val. es.
	0		"	0	
11	70	19 81	31 5	58 5	52250
11 5	78 5	19937	32	58	52992
12	78	20791	32 5	57 5	53730
12 5	77 5	21644	33	57	54464
13	77	22496	33 5	56 5	55194
13 5	76 5	23344	34	56	55919
14	76	24192	34 5	55 5	56644
14 5	75 5	25038	35	55	57378
15	75	25882	35 5	54 5	58070
15 5	74 5	26724	36	54	58778
16	74	27564	36 5	53 5	59482
16 5	73 5	28401	37	53	60181
17	73	29237	37 5	52 5	60876
17 5	72 5	30071	38	52	61566
18	72	30902	38 5	51 5	62251
18 5	71 5	31736	39	51	62932
19	71	32567	39 5	50 5	63608
19 5	70 5	33381	40	50	64279
20	70	34202	40 5	49 5	64945
20 5	69 5	35021	41	49	65606
21	69	35837	41 5	48 5	66262
21 5	68 5	36650	42	48	66913
22	68	37461	42 5	47 5	67559
22 5	67 5	38268	43	47	68200
23	67	39073	43 5	46 5	68837
23 5	66 5	39875	44	46	69466
24	66	40674	44 5	45 5	70091
24 5	65 5	41469	45	45	70711
25	65	42262	45 5	44 5	71325
25 5	64 5	43054	46	44	71934
26	64	43837	46 5	43 5	72537
26 5	63 5	44627	47	43	73135
27	63	45419	47 5	42 5	73728
27 5	62 5	46215	48	42	74314
28	62	47017	48 5	41 5	74896
28 5	61 5	47816	49	41	75471
29	61	48618	49 5	40 5	76041
29 5	60 5	49422	50	40	76604
30	60	50230	50 5	39 5	77162
30 5	59 5	51034	51	39	77715
31	59	51844	51 5	38 5	78261

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
0	0		0		
52	38	·78801	71·5	18·5	·94832
52·5	37·5	·79335	72	18	·95106
53	37	·79861	72·5	17·5	·95372
53·5	36·5	·80386	73	17	·95630
54	36	·80902	73·5	16·5	·95882
54·5	35·5	·81412	74	16	·96126
55	35	·81915	74·5	15·5	·96363
55·5	34·5	·82413	75	15	·96593
56	34	·82904	75·5	14·5	·96815
56·5	33·5	·83389	76	14	·97030
57	33	·83867	76·5	13·5	·97237
57·5	32·5	·84339	77	13	·97437
58	32	·84805	77·5	12·5	·97630
58·5	31·5	·85264	78	12	·97815
59	31	·85717	78·5	11·5	·97992
59·5	30·5	·86163	79	11	·98163
60	30	·86602	79·5	10·5	·98325
60·5	29·5	·87036	80	10	·98481
61	29	·87462	80·5	9·5	·98629
61·5	28·5	·87882	81	9	·98769
62	28	·88295	81·5	8·5	·98902
62·5	27·5	·88701	82	8	·99027
63	27	·89101	82·5	7·5	·99144
63·5	26·5	·89493	83	7	·99255
64	26	·89879	83·5	6·5	·99357
64·5	25·5	·90258	84	6	·99452
65	25	·90631	84·5	5·5	·99540
65·5	24·5	·90996	85	5	·99619
66	24	·91354	85·5	4·5	·99692
66·5	23·5	·91706	86	4	·99756
67	23	·92050	86·5	3·5	·99813
67·5	22·5	·92388	87	3	·99863
68	22	·92718	87·5	2·5	·99905
68·5	21·5	·93042	88	2	·99939
69	21	·93358	88·5	1·5	·99966
69·5	20·5	·93667	89	1	·99985
70	20	·93969	89·5	0·5	·99996
70·5	19·5	·94264	90	0	1·000000
71	19	·94552			

TABLE 7.—TANGENTS AND COTANGENTS OF ANGLES FROM 0 TO 90°.*

(RADIUS = 1.)

Tangents of Angles.	Cotangents of Angles.	Values.	Tangents of Angles.	Cotangents of Angles.	Values.
0	90	00000	18.5	71.5	33459
0.5	89.5	00873	19	71	34433
1	89	01745	19.5	70.5	35412
1.5	88.5	02619	20	70	36397
2	88	03492	20.5	69.5	37388
2.5	87.5	04366	21	69	38386
3	87	05241	21.5	68.5	39391
3.5	86.5	06116	22	68	40403
4	86	06993	22.5	67.5	41421
4.5	85.5	07870	23	67	42447
5	85	08749	23.5	66.5	43481
5.5	84.5	09629	24	66	44523
6	84	10510	24.5	65.5	45573
6.5	83.5	11394	25	65	46631
7	83	12278	25.5	64.5	47698
7.5	82.5	13165	26	64	48773
8	82	14054	26.5	63.5	49858
8.5	81.5	14945	27	63	50952
9	81	15838	27.5	62.5	52057
9.5	80.5	16734	28	62	53171
10	80	17633	28.5	61.5	54296
10.5	79.5	18534	29	61	55431
11	79	19438	29.5	60.5	56577
11.5	78.5	20345	30	60	57735
12	78	21256	30.5	59.5	58904
12.5	77.5	22169	31	59	60086
13	77	23087	31.5	58.5	61280
13.5	76.5	24008	32	58	62487
14	76	24933	32.5	57.5	63708
14.5	75.5	25862	33	57	64941
15	75	26795	33.5	56.5	66189
15.5	74.5	27732	34	56	67451
16	74	28674	34.5	55.5	68728
16.5	73.5	29621	35	55	70021
17	73	30573	35.5	54.5	71329
17.5	72.5	31530	36	54	72654
18	72	32492	36.5	53.5	73995

* See Introduction, article, p. 6.

Tangents of Angles.	Cotan- gents of Angles.	Values.	Tangents of Angles.	Cotan- gents of Angles.	Values.
°	°		°	°	
37	53	·75355	57·5	32·5	1·56969
37·5	52·5	·76763	58	32	1·60033
38	52	·78129	58·5	31·5	1·63185
38·5	51·5	·79544	59	31	1·66428
39	51	·80978	59·5	30·5	1·69766
39·5	50·5	·82434	60	30	1·73205
40	50	·83910	60·5	29·5	1·76749
40·5	49·5	·85408	61	29	1·80405
41	49	·86929	61·5	28·5	1·84174
41·5	48·5	·88472	62	28	1·88073
42	48	·90040	62·5	27·5	1·92098
42·5	47·5	·91633	63	27	1·96261
43	47	·93251	63·5	26·5	2·00569
43·5	46·5	·94896	64	26	2·05030
44	46	·96569	64·5	25·5	2·09654
44·5	45·5	·98270	65	25	2·14451
45	45	1·00000	65·5	24·5	2·19430
45·5	44·5	1·01761	66	24	2·24604
46	44	1·03553	66·5	23·5	2·29984
46·5	43·5	1·05378	67	23	2·35585
47	43	1·07237	67·5	22·5	2·41421
47·5	42·5	1·09131	68	22	2·47509
48	42	1·11061	68·5	21·5	2·53865
48·5	41·5	1·13029	69	21	2·60509
49	41	1·15037	69·5	20·5	2·67462
49·5	40·5	1·17085	70	20	2·74748
50	40	1·19175	70·5	19·5	2·82391
50·5	39·5	1·21310	71	19	2·90421
51	39	1·23490	71·5	18·5	2·98868
51·5	38·5	1·25717	72	18	3·07768
52	38	1·27994	72·5	17·5	3·17159
52·5	37·5	1·30323	73	17	3·27085
53	37	1·32704	73·5	16·5	3·37594
53·5	36·5	1·35142	74	16	3·48741
54	36	1·37638	74·5	15·5	3·60588
54·5	35·5	1·40195	75	15	3·73205
55	35	1·42815	75·5	14·5	3·86671
55·5	34·5	1·45501	76	14	4·01078
56	34	1·48256	76·5	13·5	4·16530
56·5	33·5	1·51084	77	13	4·33148
57	33	1·53986	77·5	12·5	4·51071

Tangents of Angles	Cotangents of Angles	Values	Tangents of Angles	Cotangents of Angles	Values
78	12	4.70463	84.5	5.7	10.38540
78.5	11.5	4.91516	85	5	11.13065
79	11	5.14455	85.5	4	12.00620
79.5	10.5	5.39552	86	4	14.30067
80	10	5.67128	86.5	3.5	16.34985
80.5	9.5	5.97576	87	3	19.08114
81	9	6.31375	87.5	2.5	22.90377
81.5	8.5	6.69116	88	2	28.63625
82	8	7.11537	88.5	1.5	38.18846
82.5	7.5	7.59075	89	1	50.28996
83	7	8.14435	89.5	0.5	114.58806
83.5	6.5	8.77689	90	0	infinite
84	6	9.51436			

TABLE 8. LENGTHS OF CIRCULAR ARCS FROM $^{\circ}$ TO 180°
(RADIUS = 1)

Deg	Length	Deg	Length	Deg	Length	Deg	Length
1	.017	20	.349	39	.6807	58	1.0123
2	.0349	21	.3665	40	.6981	59	1.0297
3	.0524	22	.3840	41	.7150	60	1.0472
4	.0698	23	.4014	42	.7330	61	1.0647
5	.0873	24	.4189	43	.7507	62	1.0821
6	.1047	25	.4363	44	.7679	63	1.0996
7	.1222	26	.4538	45	.7854	64	1.1170
8	.1396	27	.4712	46	.8029	65	1.1345
9	.1571	28	.4887	47	.8203	66	1.1519
10	.1745	29	.5061	48	.8378	67	1.1694
11	.1920	30	.5236	49	.8552	68	1.1868
12	.2094	31	.5411	50	.8727	69	1.2043
13	.2269	32	.5587	51	.8901	70	1.2217
14	.2443	33	.5760	52	.9076	71	1.2392
15	.2618	34	.5934	53	.9250	72	1.2566
16	.2793	35	.6109	54	.9425	73	1.2741
17	.2967	36	.6283	55	.9599	74	1.2915
18	.3142	37	.6458	56	.9773	75	1.3090
19	.3316	38	.6632	57	.9948	76	1.3265

* See Introduction and p. 1.

LENGTHS OF CIRCULAR ARCS

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Deg.	Length	Deg.	Length	Deg.	Length	Deg.	Length
77	1.3430	103	1.7977	129	2.2510	155	2.7053
78	1.3613	104	1.8151	130	2.2690	156	2.7227
79	1.3788	105	1.8326	131	2.2864	157	2.7402
80	1.3963	106	1.8500	132	2.3038	158	2.7576
81	1.4137	107	1.8675	133	2.3213	159	2.7751
82	1.4312	108	1.8850	134	2.3387	160	2.7925
83	1.4486	109	1.9024	135	2.3562	161	2.8100
84	1.4661	110	1.9199	136	2.3736	162	2.8274
85	1.4835	111	1.9373	137	2.3911	163	2.8449
86	1.5010	112	1.9548	138	2.4085	164	2.8623
87	1.5184	113	1.9722	139	2.4260	165	2.8798
88	1.5359	114	1.9897	140	2.4434	166	2.8972
89	1.5533	115	2.0071	141	2.4609	167	2.9147
90	1.5708	116	2.0246	142	2.4783	168	2.9321
91	1.5882	117	2.0420	143	2.4958	169	2.9496
92	1.6057	118	2.0595	144	2.5132	170	2.9671
93	1.6231	119	2.0769	145	2.5307	171	2.9845
94	1.6406	120	2.0944	146	2.5481	172	3.0020
95	1.6580	121	2.1118	147	2.5656	173	3.0194
96	1.6755	122	2.1293	148	2.5830	174	3.0369
97	1.6929	123	2.1467	149	2.6005	175	3.0543
98	1.7104	124	2.1642	150	2.6179	176	3.0718
99	1.7278	125	2.1816	151	2.6354	177	3.0892
100	1.7453	126	2.1991	152	2.6528	178	3.1067
101	1.7628	127	2.2165	153	2.6703	179	3.1241
102	1.7802	128	2.2340	154	2.6877	180	3.1416

TABLE 9. LENGTHS OF CIRCULAR ARCS, UP TO A SEMI CIRCLE.*

(CHORD = 1)

Height	Length	Height	Length	Height	Length	Height	Length
.001	1.00002	.009	1.00032	.017	1.00078	.025	1.00167
.002	1.00002	.010	1.00027	.018	1.00081	.026	1.00182
.003	1.00003	.011	1.00035	.019	1.00097	.027	1.00196
.004	1.00004	.012	1.00038	.020	1.00107	.028	1.00210
.005	1.00005	.013	1.00041	.021	1.00117	.029	1.00225
.006	1.00006	.014	1.00050	.022	1.00128	.030	1.00240
.007	1.00008	.015	1.00061	.023	1.00140	.031	1.00256
.008	1.00017	.016	1.00069	.024	1.00153	.032	1.00273

* See Introduction, note, p. 7.

No.	Log	No.	Log	No.	Log	No.	Log
4.37	1.4748	4.81	1.5707	5.23	1.6544	5.66	1.73842
4.38	1.4770	4.82	1.5728	5.24	1.6563	5.67	1.73524
4.39	1.4793	4.83	1.5748	5.25	1.6582	5.68	1.73704
4.40	1.4816	4.84	1.5769	5.26	1.6601	5.69	1.73877
4.41	1.4839	4.85	1.5790	5.27	1.6620	5.70	1.74052
4.42	1.4861	4.86	1.5810	5.28	1.6639	5.71	1.74228
4.43	1.4884	4.87	1.5831	5.29	1.6658	5.72	1.74404
4.44	1.4907	4.88	1.5851	5.30	1.6677	5.73	1.74579
4.45	1.4929	4.89	1.5872	5.31	1.6696	5.74	1.74755
4.46	1.4951	4.90	1.5892	5.32	1.6715	5.75	1.74924
4.47	1.4973	4.91	1.5913	5.33	1.6734	5.76	1.75092
4.48	1.4996	4.92	1.5934	5.34	1.6752	5.77	1.75273
4.49	1.5019	4.93	1.5953	5.35	1.6771	5.78	1.75444
4.50	1.5041	4.94	1.5974	5.36	1.6790	5.79	1.75612
4.51	1.5063	4.95	1.5994	5.37	1.6808	5.80	1.75792
4.52	1.5085	4.96	1.6014	5.38	1.6827	5.81	1.75963
4.53	1.5107	4.97	1.6034	5.39	1.6845	5.82	1.76135
4.54	1.5129	4.98	1.6054	5.40	1.6864	5.83	1.76308
4.55	1.5151	4.99	1.6074	5.41	1.6882	5.84	1.76478
4.56	1.5173	5.00	1.6094	5.42	1.6901	5.85	1.76644
4.57	1.5195	5.01	1.6114	5.43	1.6919	5.86	1.76812
4.58	1.5217	5.02	1.6134	5.44	1.6938	5.87	1.76982
4.59	1.5239	5.03	1.6154	5.45	1.6956	5.88	1.77152
4.60	1.5261	5.04	1.6174	5.46	1.6974	5.89	1.77323
4.61	1.5282	5.05	1.6194	5.47	1.6993	5.90	1.77493
4.62	1.5304	5.06	1.6214	5.48	1.7011	5.91	1.77663
4.63	1.5326	5.07	1.6234	5.49	1.7029	5.92	1.77833
4.64	1.5347	5.08	1.6253	5.50	1.7047	5.93	1.78003
4.65	1.5369	5.09	1.6273	5.51	1.7066	5.94	1.78173
4.66	1.5390	5.10	1.6292	5.52	1.7084	5.95	1.78343
4.67	1.5412	5.11	1.6312	5.53	1.7102	5.96	1.78513
4.68	1.5433	5.12	1.6331	5.54	1.7120	5.97	1.78683
4.69	1.5454	5.13	1.6351	5.55	1.7138	5.98	1.78853
4.70	1.5476	5.14	1.637	5.56	1.7156	5.99	1.79023
4.71	1.5497	5.15	1.6390	5.57	1.7174	6.00	1.79193
4.72	1.5518	5.16	1.6409	5.58	1.7192	6.01	1.79363
4.73	1.5539	5.17	1.6429	5.59	1.7210	6.02	1.79533
4.74	1.5560	5.18	1.6448	5.60	1.7228	6.03	1.79703
4.75	1.5581	5.19	1.6467	5.61	1.7246	6.04	1.79873
4.76	1.5602	5.20	1.6487	5.62	1.7264	6.05	1.80043
4.77	1.5623	5.21	1.6506	5.63	1.7281	6.06	1.80213
4.78	1.5644	5.22	1.6525	5.64	1.7299	6.07	1.80383
4.79	1.5665			5.65	1.7317	6.08	1.80553

No.	Log.	No.	Log.	No.	Log.	No.	Log.
6.09	1.80146	6.52	1.87449	6.95	1.93887	7.38	1.99888
6.10	1.80083	6.53	1.87644	6.96	1.9402	7.39	2.0001
6.11	1.80099	6.54	1.87779	6.97	1.9416	7.40	2.0015
6.12	1.81116	6.55	1.8795	6.98	1.9430	7.41	2.0028
6.13	1.8132	6.56	1.8810	6.99	1.9445	7.42	2.0042
6.14	1.8148	6.57	1.8825	7.00	1.9459	7.43	2.0055
6.15	1.8165	6.58	1.8840	7.01	1.9473	7.44	2.0069
6.16	1.8181	6.59	1.8856	7.02	1.9488	7.45	2.0082
6.17	1.8197	6.60	1.8871	7.03	1.9502	7.46	2.0096
6.18	1.8213	6.61	1.8886	7.04	1.9516	7.47	2.0109
6.19	1.8229	6.62	1.8901	7.05	1.9530	7.48	2.0122
6.20	1.8245	6.63	1.8916	7.06	1.9544	7.49	2.0136
6.21	1.8262	6.64	1.8931	7.07	1.9559	7.50	2.0149
6.22	1.8278	6.65	1.8946	7.08	1.9573	7.51	2.0162
6.23	1.8294	6.66	1.8961	7.09	1.9587	7.52	2.0176
6.24	1.8310	6.67	1.8976	7.10	1.9601	7.53	2.0189
6.25	1.8326	6.68	1.8991	7.11	1.9615	7.54	2.0202
6.26	1.8342	6.69	1.9006	7.12	1.9629	7.55	2.0215
6.27	1.8358	6.70	1.9021	7.13	1.9643	7.56	2.0229
6.28	1.8374	6.71	1.9036	7.14	1.9657	7.57	2.0242
6.29	1.8390	6.72	1.9051	7.15	1.9671	7.58	2.0255
6.30	1.8405	6.73	1.9066	7.16	1.9685	7.59	2.0269
6.31	1.8421	6.74	1.9081	7.17	1.9699	7.60	2.0281
6.32	1.8437	6.75	1.9095	7.18	1.9713	7.61	2.0295
6.33	1.8453	6.76	1.9110	7.19	1.9727	7.62	2.0308
6.34	1.8469	6.77	1.9125	7.20	1.9741	7.63	2.0321
6.35	1.8485	6.78	1.9140	7.21	1.9755	7.64	2.0334
6.36	1.8500	6.79	1.9155	7.22	1.9769	7.65	2.0347
6.37	1.8516	6.80	1.9169	7.23	1.9782	7.66	2.0360
6.38	1.8532	6.81	1.9184	7.24	1.9796	7.67	2.0373
6.39	1.8547	6.82	1.9199	7.25	1.9810	7.68	2.0386
6.40	1.8563	6.83	1.9213	7.26	1.9824	7.69	2.0399
6.41	1.8579	6.84	1.9228	7.27	1.9838	7.70	2.0412
6.42	1.8594	6.85	1.9242	7.28	1.9851	7.71	2.0425
6.43	1.8610	6.86	1.9257	7.29	1.9865	7.72	2.0438
6.44	1.8625	6.87	1.9272	7.30	1.9879	7.73	2.0451
6.45	1.8641	6.88	1.9286	7.31	1.9892	7.74	2.0464
6.46	1.8656	6.89	1.9301	7.32	1.9906	7.75	2.0477
6.47	1.8672	6.90	1.9315	7.33	1.9920	7.76	2.0490
6.48	1.8687	6.91	1.9330	7.34	1.9933	7.77	2.0503
6.49	1.8703	6.92	1.9344	7.35	1.9947	7.78	2.0516
6.50	1.8719	6.93	1.9359	7.36	1.9961	7.79	2.0529
6.51	1.8735	6.94	1.9373	7.37	1.9974	7.80	2.0542

No.	Log	No.	Log	No.	Log	No.	Log
781	2.0554	824	2.1090	867	2.1599	910	2.2083
782	2.0567	825	2.1102	868	2.1610	911	2.2094
783	2.0580	826	2.1114	869	2.1622	912	2.2105
784	2.0592	827	2.1126	870	2.1633	913	2.2116
785	2.0605	828	2.1138	871	2.1645	914	2.2127
786	2.0618	829	2.1150	872	2.1656	915	2.2138
787	2.0631	830	2.1163	873	2.1668	916	2.2148
788	2.0643	831	2.1175	874	2.1679	917	2.2159
789	2.0656	832	2.1187	875	2.1691	918	2.2170
790	2.0669	833	2.1199	876	2.1702	919	2.2181
791	2.0681	834	2.1211	877	2.1713	920	2.2192
792	2.0694	835	2.1223	878	2.1724	921	2.2203
793	2.0707	836	2.1235	879	2.1736	922	2.2214
794	2.0719	837	2.1247	880	2.1748	923	2.2225
795	2.0732	838	2.1258	881	2.1759	924	2.2235
796	2.0744	839	2.1270	882	2.1770	925	2.2246
797	2.0757	840	2.1282	883	2.1782	926	2.2257
798	2.0769	841	2.1294	884	2.1793	927	2.2268
799	2.0782	842	2.1306	885	2.1804	928	2.2279
800	2.0794	843	2.1318	886	2.1815	929	2.2289
801	2.0807	844	2.1330	887	2.1827	930	2.2300
802	2.0819	845	2.1342	888	2.1838	931	2.2311
803	2.0832	846	2.1353	889	2.1849	932	2.2322
804	2.0844	847	2.1365	890	2.1861	933	2.2332
805	2.0857	848	2.1377	891	2.1872	934	2.2343
806	2.0869	849	2.1389	892	2.1883	935	2.2354
807	2.0882	850	2.1401	893	2.1894	936	2.2364
808	2.0894	851	2.1412	894	2.1905	937	2.2375
809	2.0906	852	2.1424	895	2.1917	938	2.2386
810	2.0919	853	2.1436	896	2.1928	939	2.2396
811	2.0931	854	2.1448	897	2.1939	940	2.2407
812	2.0943	855	2.1459	898	2.1950	941	2.2418
813	2.0956	856	2.1471	899	2.1961	942	2.2428
814	2.0968	857	2.1483	900	2.1972	943	2.2439
815	2.0980	858	2.1494	901	2.1983	944	2.2450
816	2.0992	859	2.1506	902	2.1994	945	2.2460
817	2.1005	860	2.1518	903	2.2006	946	2.2471
818	2.1017	861	2.1529	904	2.2017	947	2.2481
819	2.1029	862	2.1541	905	2.2028	948	2.2492
820	2.1041	863	2.1552	906	2.2039	949	2.2502
821	2.1054	864	2.1564	907	2.2050	950	2.2513
822	2.1066	865	2.1576	908	2.2061	951	2.2523
823	2.1078	866	2.1587	909	2.2072	952	2.2534

No.	Log.	No.	Log.	No.	Log.	No.	Log.
9-53	2-2544	9-73	2-2752	9-93	2-2956	13-25	2-5840
9-54	2-2555	9-74	2-2762	9-94	2-2966	13-50	2-6027
9-55	2-2565	9-75	2-2773	9-95	2-2976	13-75	2-6211
9-56	2-2576	9-76	2-2783	9-96	2-2986	14-00	2-6391
9-57	2-2586	9-77	2-2793	9-97	2-2996	14-25	2-6567
9-58	2-2597	9-78	2-2803	9-98	2-3006	14-50	2-6740
9-59	2-2607	9-79	2-2814	9-99	2-3016	14-75	2-6913
9-60	2-2618	9-80	2-2824	10-00	2-3026	15-00	2-7081
9-61	2-2628	9-81	2-2834	10-25	2-3279	15-50	2-7408
9-62	2-2638	9-82	2-2844	10-50	2-3513	16-00	2-7726
9-63	2-2649	9-83	2-2854	10-75	2-3749	16-50	2-8034
9-64	2-2659	9-84	2-2865	11-00	2-3979	17-00	2-8332
9-65	2-2670	9-85	2-2875	11-25	2-4201	17-50	2-8621
9-66	2-2680	9-86	2-2885	11-50	2-4430	18-00	2-8904
9-67	2-2690	9-87	2-2895	11-75	2-4636	18-50	2-9173
9-68	2-2701	9-88	2-2905	12-00	2-4849	19-00	2-9444
9-69	2-2711	9-89	2-2915	12-25	2-5052	19-50	2-9703
9-70	2-2721	9-90	2-2925	12-50	2-5262	20-00	2-9957
9-71	2-2732	9-91	2-2935	12-75	2-5455		
9-72	2-2742	9-92	2-2946	13-00	2-5649		

TABLE 6.—SINES AND COSINES OF ANGLES FROM
0° TO 90°.*

(RADIUS = 1.)

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
0	90	00000	5-5	84-5	09585
0-5	89-5	00873	6	84	10453
1	89	01745	6-5	83-5	11320
1-5	88-5	02618	7	83	12187
2	88	03490	7-5	82-5	13053
2-5	87-5	04362	8	82	13917
3	87	05234	8-5	81-5	14781
3-5	86-5	06105	9	81	15643
4	86	06976	9-5	80-5	16505
4-5	85-5	07846	10	80	17365
5	85	08716	10-5	79-5	18224

* See Introduction, ante, p. 6.

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
11	78	19081	31.5	58.5	52250
11.5	78.5	19937	32	58	52902
12	78	20791	32.5	57.5	53573
12.5	77.5	21644	33	57	54246
13	77	22495	33.5	56.5	54919
13.5	76.5	23344	34	56	55591
14	76	24192	34.5	55.5	56261
14.5	75.5	25038	35	55	56928
15	75	25882	35.5	54.5	57590
15.5	74.5	26724	36	54	58248
16	74	27564	36.5	53.5	58902
16.5	73.5	28401	37	53	59551
17	73	29237	37.5	52.5	60206
17.5	72.5	30071	38	52	60856
18	72	30902	38.5	51.5	61501
18.5	71.5	31730	39	51	62142
19	71	32557	39.5	50.5	62778
19.5	70.5	33381	40	50	63409
20	70	34202	40.5	49.5	64036
20.5	69.5	35021	41	49	64659
21	69	35837	41.5	48.5	65277
21.5	68.5	36651	42	48	65891
22	68	37461	42.5	47.5	66500
22.5	67.5	38268	43	47	67105
23	67	39073	43.5	46.5	67706
23.5	66.5	39875	44	46	68303
24	66	40674	44.5	45.5	68896
24.5	65.5	41469	45	45	69485
25	65	42262	45.5	44.5	70071
25.5	64.5	43051	46	44	70653
26	64	43837	46.5	43.5	71231
26.5	63.5	44620	47	43	71805
27	63	45399	47.5	42.5	72375
27.5	62.5	46175	48	42	72941
28	62	46947	48.5	41.5	73503
28.5	61.5	47715	49	41	74061
29	61	48481	49.5	40.5	74614
29.5	60.5	49242	50	40	75163
30	60	50000	50.5	39.5	75707
30.5	59.5	50754	51	39	76247
31	59	51504	51.5	38.5	76782

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
°	°		°	°	
52	38	·78801	71·5	18·5	·94832
52·5	37·5	·79335	72	18	·95106
53	37	·79861	72·5	17·5	·95372
53·5	36·5	·80386	73	17	·95630
54	36	·80902	73·5	16·5	·95882
54·5	35·5	·81412	74	16	·96126
55	35	·81915	74·5	15·5	·96363
55·5	34·5	·82413	75	15	·96593
56	34	·82904	75·5	14·5	·96815
56·5	33·5	·83389	76	14	·97030
57	33	·83867	76·5	13·5	·97237
57·5	32·5	·84339	77	13	·97437
58	32	·84805	77·5	12·5	·97630
58·5	31·5	·85264	78	12	·97815
59	31	·85717	78·5	11·5	·97992
59·5	30·5	·86163	79	11	·98163
60	30	·86602	79·5	10·5	·98325
60·5	29·5	·87036	80	10	·98481
61	29	·87462	80·5	9·5	·98629
61·5	28·5	·87882	81	9	·98769
62	28	·88295	81·5	8·5	·98902
62·5	27·5	·88701	82	8	·99027
63	27	·89101	82·5	7·5	·99144
63·5	26·5	·89493	83	7	·99255
64	26	·89879	83·5	6·5	·99357
64·5	25·5	·90258	84	6	·99452
65	25	·90631	84·5	5·5	·99540
65·5	24·5	·90996	85	5	·99619
66	24	·91354	85·5	4·5	·99692
66·5	23·5	·91706	86	4	·99756
67	23	·92050	86·5	3·5	·99813
67·5	22·5	·92388	87	3	·99863
68	22	·92718	87·5	2·5	·99905
68·5	21·5	·93042	88	2	·99939
69	21	·93358	88·5	1·5	·99966
69·5	20·5	·93667	89	1	·99985
70	20	·93969	89·5	0·5	·99996
70·5	19·5	·94261	90	0	1·000000
71	19	·94552			

TABLE 7.—TANGENTS AND COTANGENTS OF ANGLES FROM
0° TO 90°.*

(RADIUS = 1.)

Tangents of Angles.	Cotan- gents of Angles.	Values.	Tangents of Angles.	Cotan- gents of Angles.	Values.
0	90	·00000	18·5	71·5	·33459
0·5	89·5	·00873	19	71	·34433
1	89	·01745	19·5	70·5	·35412
1·5	88·5	·02619	20	70	·36397
2	88	·03492	20·5	69·5	·37388
2·5	87·5	·04366	21	69	·38386
3	87	·05241	21·5	68·5	·39391
3·5	86·5	·06116	22	68	·40403
4	86	·06993	22·5	67·5	·41421
4·5	85·5	·07870	23	67	·42447
5	85	·08749	23·5	66·5	·43481
5·5	84·5	·09629	24	66	·44523
6	84	·10510	24·5	65·5	·45573
6·5	83·5	·11394	25	65	·46631
7	83	·12278	25·5	64·5	·47698
7·5	82·5	·13165	26	64	·48773
8	82	·14054	26·5	63·5	·49858
8·5	81·5	·14945	27	63	·50952
9	81	·15838	27·5	62·5	·52057
9·5	80·5	·16734	28	62	·53171
10	80	·17633	28·5	61·5	·54296
10·5	79·5	·18534	29	61	·55431
11	79	·19438	29·5	60·5	·56577
11·5	78·5	·20345	30	60	·57735
12	78	·21256	30·5	59·5	·58904
12·5	77·5	·22169	31	59	·60086
13	77	·23087	31·5	58·5	·61280
13·5	76·5	·24008	32	58	·62487
14	76	·24933	32·5	57·5	·63708
14·5	75·5	·25862	33	57	·64941
15	75	·26795	33·5	56·5	·66189
15·5	74·5	·27732	34	56	·67451
16	74	·28674	34·5	55·5	·68728
16·5	73·5	·29621	35	55	·70021
17	73	·30573	35·5	54·5	·71329
17·5	72·5	·31530	36	54	·72654
18	72	·32492	36·5	53·5	·73996

* See Introduction, ante, p. 6.

its s.	Cotan- gents of Angles.	Values.	Tangents of Angles.	Cotan- gents of Angles.	Values.
	°		°	°	
	53	·75355	57·5	32·5	1·56969
	52·5	·76763	58	32	1·60033
	52	·78129	58·5	31·5	1·63185
	51·5	·79544	59	31	1·66428
	51	·80978	59·5	30·5	1·69766
	50·5	·82434	60	30	1·73205
	50	·83910	60·5	29·5	1·76749
	49·5	·85408	61	29	1·80405
	49	·86929	61·5	28·5	1·84174
	48·5	·88472	62	28	1·88073
	48	·90040	62·5	27·5	1·92098
	47·5	·91633	63	27	1·96261
	47	·93251	63·5	26·5	2·00569
	46·5	·94896	64	26	2·05030
	46	·96569	64·5	25·5	2·09654
	45·5	·98270	65	25	2·14451
	45	1·00000	65·5	24·5	2·19430
	44·5	1·01761	66	24	2·24604
	44	1·03553	66·5	23·5	2·29984
	43·5	1·05378	67	23	2·35585
	43	1·07237	67·5	22·5	2·41421
	42·5	1·09131	68	22	2·47509
	42	1·11061	68·5	21·5	2·53865
	41·5	1·13029	69	21	2·60509
	41	1·15037	69·5	20·5	2·67462
	40·5	1·17085	70	20	2·74748
	40	1·19175	70·5	19·5	2·82391
	39·5	1·21310	71	19	2·90421
	39	1·23490	71·5	18·5	2·98868
	38·5	1·25717	72	18	3·07768
	38	1·27994	72·5	17·5	3·17159
	37·5	1·30323	73	17	3·27085
	37	1·32704	73·5	16·5	3·37594
	36·5	1·35142	74	16	3·48741
	36	1·37638	74·5	15·5	3·60588
	35·5	1·40195	75	15	3·73205
	35	1·42815	75·5	14·5	3·86671
	34·5	1·45501	76	14	4·01078
	34	1·48256	76·5	13·5	4·16530
	33·5	1·51084	77	13	4·33148
33	1·53986		77·5	12·5	4·51071

Tangents of Angles	Cotangents of Angles	Values	Tangents of Angles	Cotangents of Angles	Values
	°			°	
78	12	4.70463	84.5	5.5	10.48540
78.5	11.5	4.91516	85	5	11.43005
79	11	5.14455	85.5	4.5	12.76420
79.5	10.5	5.36552	86	4	14.30667
80	10	5.6128	86.5	3.5	16.34985
80.5	9.5	5.91516	87	3	19.08114
81	9	6.31375	87.5	2.5	22.36377
81.5	8.5	6.69116	88	2	28.63625
82	8	7.11537	88.5	1.5	38.18846
82.5	7.5	7.59575	89	1	57.28996
83	7	8.14435	89.5	0.5	114.58865
83.5	6.5	8.77689	90	0	infinite.
84	6	9.51436			

TABLE 8. LENGTHS OF CIRCULAR ARCS FROM 1' TO 180'
(RADIUS = 1.)

Deg	Length	Deg	Length	Deg	Length	Deg	Length
1	.1736	20	.3491	39	.6807	58	1.0123
2	.0349	21	.3663	40	.6981	59	1.0297
3	.0524	22	.3840	41	.7156	60	1.0472
4	.0698	23	.4014	42	.7330	61	1.0647
5	.0873	24	.4189	43	.7507	62	1.0821
6	.1047	25	.4355	44	.7679	63	1.0996
7	.1222	26	.4538	45	.7854	64	1.1170
8	.1396	27	.4712	46	.8029	65	1.1345
9	.1571	28	.4887	47	.8203	66	1.1519
10	.1745	29	.5061	48	.8378	67	1.1694
11	.192	30	.5236	49	.8552	68	1.1868
12	.2094	31	.5411	50	.8727	69	1.2043
13	.2269	32	.5587	51	.8902	70	1.2218
14	.2443	33	.5760	52	.9076	71	1.2392
15	.2618	34	.5934	53	.9250	72	1.2567
16	.2793	35	.6109	54	.9425	73	1.2741
17	.2967	36	.6283	55	.9599	74	1.2916
18	.3142	37	.6458	56	.9773	75	1.3090
19	.3316	38	.6632	57	.9948	76	1.3265

See Introduction, note, p. 7

Deg	Length	Deg	Length	Deg	Length	Deg	Length
77	1.3439	103	1.7977	129	2.2515	155	2.7053
78	1.3443	104	1.8151	130	2.2660	156	2.7227
79	1.3488	105	1.8326	131	2.2804	157	2.7402
80	1.3563	106	1.8500	132	2.2948	158	2.7576
81	1.3637	107	1.8675	133	2.3093	159	2.7751
82	1.3712	108	1.8850	134	2.3237	160	2.7927
83	1.3787	109	1.9024	135	2.3382	161	2.8101
84	1.3861	110	1.9199	136	2.3526	162	2.8276
85	1.3936	111	1.9373	137	2.3671	163	2.8449
86	1.4010	112	1.9548	138	2.3815	164	2.8623
87	1.4084	113	1.9722	139	2.3960	165	2.8798
88	1.4159	114	1.9897	140	2.4104	166	2.8972
89	1.4233	115	2.0071	141	2.4249	167	2.9147
90	1.4308	116	2.0246	142	2.4393	168	2.9321
91	1.4382	117	2.0420	143	2.4538	169	2.9496
92	1.4457	118	2.0595	144	2.4682	170	2.9670
93	1.4531	119	2.0769	145	2.4827	171	2.9845
94	1.4606	120	2.0944	146	2.4971	172	3.0019
95	1.4680	121	2.1118	147	2.5116	173	3.0194
96	1.4755	122	2.1293	148	2.5260	174	3.0368
97	1.4829	123	2.1467	149	2.5405	175	3.0543
98	1.4904	124	2.1642	150	2.5549	176	3.0717
99	1.4978	125	2.1816	151	2.5694	177	3.0892
100	1.5053	126	2.1991	152	2.5838	178	3.1066
101	1.5127	127	2.2165	153	2.5983	179	3.1241
102	1.5202	128	2.2340	154	2.6127	180	3.1416

TABLE 9 — LENGTHS OF CIRCULAR ARCS, UP TO A
SEMI-CIRCLE.*
(CHORD = 1.)

Height	Length	Height	Length	Height	Length	Height	Length
001	1.00002	009	1.00022	017	1.00076	025	1.00167
002	1.00002	010	1.00027	018	1.00081	026	1.00182
003	1.00003	011	1.00032	019	1.00097	027	1.00206
004	1.00004	012	1.00038	020	1.00117	028	1.00231
005	1.00007	013	1.00045	021	1.00137	029	1.00255
006	1.00010	014	1.00053	022	1.00158	030	1.00280
007	1.00013	015	1.00061	023	1.00180	031	1.00304
008	1.00017	016	1.00069	024	1.00203	032	1.00329

* See Introduction, note, p. 1.

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
·033	1·00289	·076	1·01533	·119	1·03734	·162	1·06858
·034	1·00307	·077	1·01573	·120	1·03797	·163	1·06941
·035	1·00327	·078	1·01614	·121	1·03860	·164	1·07025
·036	1·00345	·079	1·01656	·122	1·03923	·165	1·07109
·037	1·00364	·080	1·01698	·123	1·03987	·166	1·07194
·038	1·00384	·081	1·01741	·124	1·04051	·167	1·07279
·039	1·00405	·082	1·01784	·125	1·04116	·168	1·07365
·040	1·00426	·083	1·01828	·126	1·04181	·169	1·07451
·041	1·00447	·084	1·01872	·127	1·04247	·170	1·07537
·042	1·00469	·085	1·01916	·128	1·04313	·171	1·07624
·043	1·00492	·086	1·01961	·129	1·04380	·172	1·07711
·044	1·00515	·087	1·02006	·130	1·04447	·173	1·07799
·045	1·00539	·088	1·02052	·131	1·04515	·174	1·07888
·046	1·00563	·089	1·02098	·132	1·04584	·175	1·07977
·047	1·00587	·090	1·02146	·133	1·04652	·176	1·08066
·048	1·00612	·091	1·02192	·134	1·04722	·177	1·08156
·049	1·00638	·092	1·02240	·135	1·04792	·178	1·08246
·050	1·00665	·093	1·02289	·136	1·04862	·179	1·08337
·051	1·00692	·094	1·02339	·137	1·04932	·180	1·08428
·052	1·00720	·095	1·02389	·138	1·05003	·181	1·08519
·053	1·00748	·096	1·02440	·139	1·05075	·182	1·08611
·054	1·00776	·097	1·02491	·140	1·05147	·183	1·08704
·055	1·00805	·098	1·02542	·141	1·05220	·184	1·08797
·056	1·00834	·099	1·02593	·142	1·05293	·185	1·08890
·057	1·00864	·100	1·02646	·143	1·05367	·186	1·08984
·058	1·00895	·101	1·02698	·144	1·05441	·187	1·09079
·059	1·00926	·102	1·02752	·145	1·05516	·188	1·09174
·060	1·00957	·103	1·02806	·146	1·05591	·189	1·09269
·061	1·00989	·104	1·02860	·147	1·05667	·190	1·09365
·062	1·01021	·105	1·02914	·148	1·05743	·191	1·09461
·063	1·01054	·106	1·02970	·149	1·05819	·192	1·09557
·064	1·01088	·107	1·03026	·150	1·05896	·193	1·09654
·065	1·01123	·108	1·03082	·151	1·05973	·194	1·09752
·066	1·01158	·109	1·03139	·152	1·06051	·195	1·09850
·067	1·01193	·110	1·03196	·153	1·06130	·196	1·09949
·068	1·01229	·111	1·03254	·154	1·06209	·197	1·10048
·069	1·01264	·112	1·03312	·155	1·06288	·198	1·10147
·070	1·01302	·113	1·03371	·156	1·06368	·199	1·10247
·071	1·01338	·114	1·03430	·157	1·06449	·200	1·10347
·072	1·01376	·115	1·03490	·158	1·06530	·201	1·10447
·073	1·01414	·116	1·03551	·159	1·06611	·202	1·10548
·074	1·01453	·117	1·03611	·160	1·06693	·203	1·10650
·075	1·01493	·118	1·03672	·161	1·06775	·204	1·10752

Height	Length.	Height	Length.	Height	Length.	Height	Length.
205	1.10855	248	1.15670	291	1.21259	334	1.27502
206	1.10978	249	1.15791	292	1.21377	335	1.27656
207	1.11062	250	1.15912	293	1.21515	336	1.27810
208	1.11165	251	1.16034	294	1.21654	337	1.27864
209	1.11269	252	1.16156	295	1.21794	338	1.28118
210	1.11374	253	1.16279	296	1.21933	339	1.28273
211	1.11479	254	1.16402	297	1.22073	340	1.28428
212	1.11584	255	1.16524	298	1.22213	341	1.28583
213	1.11690	256	1.16648	299	1.22354	342	1.28739
214	1.11796	257	1.16771	300	1.22495	343	1.28895
215	1.11904	258	1.16895	301	1.22636	344	1.29052
216	1.12011	259	1.17024	302	1.22778	345	1.29209
217	1.12118	260	1.17150	303	1.22920	346	1.29366
218	1.12225	261	1.17276	304	1.23065	347	1.29523
219	1.12331	262	1.17403	305	1.23206	348	1.29681
220	1.12444	263	1.17531	306	1.23349	349	1.29838
221	1.12554	264	1.17657	307	1.23492	350	1.29997
222	1.12664	265	1.17784	308	1.23636	351	1.30156
223	1.12774	266	1.17912	309	1.23780	352	1.30315
224	1.12885	267	1.18040	310	1.23926	353	1.30474
225	1.12997	268	1.18169	311	1.24070	354	1.30634
226	1.13108	269	1.18299	312	1.24216	355	1.30794
227	1.13219	270	1.18429	313	1.24361	356	1.30954
228	1.13331	271	1.18559	314	1.24507	357	1.31115
229	1.13444	272	1.18689	315	1.24654	358	1.31276
230	1.13557	273	1.18820	316	1.24801	359	1.31437
231	1.13671	274	1.18951	317	1.24948	360	1.31599
232	1.13785	275	1.19082	318	1.25095	361	1.31761
233	1.13900	276	1.19214	319	1.25243	362	1.31923
234	1.14015	277	1.19346	320	1.25391	363	1.32086
235	1.14131	278	1.19478	321	1.25540	364	1.32249
236	1.14247	279	1.19612	322	1.25689	365	1.32413
237	1.14363	280	1.19746	323	1.25838	366	1.32577
238	1.14480	281	1.19880	324	1.25988	367	1.32741
239	1.14597	282	1.20014	325	1.26138	368	1.32905
240	1.14714	283	1.20149	326	1.26288	369	1.33069
241	1.14832	284	1.20284	327	1.26437	370	1.33234
242	1.14951	285	1.20419	328	1.26588	371	1.33399
243	1.15070	286	1.20555	329	1.26738	372	1.33564
244	1.15189	287	1.20691	330	1.26889	373	1.33730
245	1.15308	288	1.20827	331	1.27041	374	1.33895
246	1.15428	289	1.20964	332	1.27195	375	1.34060
247	1.15548	290	1.21202	333	1.27349	376	1.34225

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
377	1.34396	408	1.39724	439	1.45327	470	1.51185
378	1.34563	409	1.39900	440	1.45512	471	1.51376
379	1.34731	410	1.40077	441	1.45697	472	1.51571
380	1.34899	411	1.40254	442	1.45883	473	1.51764
381	1.35068	412	1.40432	443	1.46069	474	1.51958
382	1.35237	413	1.40610	444	1.46255	475	1.52152
383	1.35406	414	1.40788	445	1.46441	476	1.52346
384	1.35575	415	1.40966	446	1.46628	477	1.52541
385	1.35744	416	1.41144	447	1.46815	478	1.52736
386	1.35914	417	1.41324	448	1.47002	479	1.52931
387	1.36084	418	1.41503	449	1.47189	480	1.53126
388	1.36254	419	1.41682	450	1.47377	481	1.53322
389	1.36425	420	1.41861	451	1.47565	482	1.53518
390	1.36596	421	1.42041	452	1.47753	483	1.53714
391	1.36767	422	1.42221	453	1.47942	484	1.53910
392	1.36939	423	1.42402	454	1.48131	485	1.54106
393	1.37111	424	1.42583	455	1.48320	486	1.54302
394	1.37283	425	1.42764	456	1.48509	487	1.54498
395	1.37455	426	1.42945	457	1.48699	488	1.54695
396	1.37628	427	1.43127	458	1.48889	489	1.54892
397	1.37801	428	1.43309	459	1.49079	490	1.55090
398	1.37974	429	1.43491	460	1.49269	491	1.55288
399	1.38148	430	1.43673	461	1.49460	492	1.55487
400	1.38322	431	1.43856	462	1.49651	493	1.55685
401	1.38496	432	1.44039	463	1.49842	494	1.55884
402	1.38671	433	1.44222	464	1.50033	495	1.56083
403	1.38846	434	1.44405	465	1.50224	496	1.56282
404	1.3902	435	1.44589	466	1.50416	497	1.56481
405	1.39196	436	1.44773	467	1.50608	498	1.56681
406	1.39372	437	1.44957	468	1.50800	499	1.56881
407	1.39548	438	1.45142	469	1.50992	500	1.57080

TABLE 10.—AREAS OF CIRCULAR SEGMENTS, UP TO A SEMICIRCLE.*

(DIAMETER OF CIRCLE = 1.)

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
001	000042	005	000471	009	001185	013	001997
002	000119	006	000619	010	001388	014	002220
003	000219	007	000779	011	001588	015	002444
004	000337	008	000952	012	001775	016	002688

See Introduction, Note, p. 7

AREA OF CIRCULAR SEGMENTS.

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Height.	Area.	Height	Area.	Height	Area.	Height	Area.
017	00219	060	01924	103	04261	148	07108
018	00329	061	01972	104	04334	147	07174
019	00347	062	02020	105	04391	146	07245
020	00375	063	02068	106	04452	145	07316
021	00403	064	02117	107	04513	144	07387
022	00431	065	02166	108	04576	143	07459
023	00461	066	02215	109	04638	142	07530
024	00492	067	02265	110	04701	141	07603
025	00523	068	02315	111	04763	140	07675
026	00555	069	02366	112	04826	139	07747
027	00587	070	02417	113	04889	138	07819
028	00619	071	02468	114	04952	137	07892
029	00653	072	02520	115	05016	136	07965
030	00687	073	02571	116	05080	135	08038
031	00721	074	02624	117	05145	134	08111
032	00756	075	02676	118	05209	133	08185
033	00792	076	02729	119	05274	132	08258
034	00828	077	02782	120	05338	131	08332
035	00864	078	02836	121	05404	130	08406
036	00901	079	02889	122	05469	129	08480
037	00939	080	02943	123	05533	128	08554
038	00977	081	02997	124	05600	127	08629
039	01015	082	03053	125	05665	126	08704
040	01054	083	03108	126	05733	125	08778
041	01093	084	03163	127	05799	124	08854
042	01133	085	03219	128	05866	123	08929
043	01173	086	03275	129	05933	122	09004
044	01214	087	03331	130	06000	121	09080
045	01255	088	03387	131	06067	120	09155
046	01297	089	03444	132	06135	119	09231
047	01340	090	03501	133	06203	118	09307
048	01382	091	03558	134	06271	117	09383
049	01425	092	03616	135	06339	116	09460
050	01468	093	03674	136	06407	115	09537
051	01512	094	03732	137	06475	114	09613
052	01556	095	03790	138	06543	113	09690
053	01601	096	03850	139	06611	112	09767
054	01646	097	03909	140	06680	111	09845
055	01691	098	03968	141	06753	110	09922
056	01737	099	04028	142	06822	109	09999
057	01783	100	04087	143	06892	108	10077
058	01830	101	04148	144	06963	107	10155
059	01877	102	04208	145	07033	106	10233

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Height	Area.	Height	Area	Height	Area	Height	Area.
189	10317	232	13815	275	17554	318	21480
190	10390	233	13899	276	17614	319	21573
191	10469	234	13984	277	17673	320	21667
192	10547	235	14069	278	17733	321	21760
193	10626	236	14154	279	17792	322	21853
194	10705	237	14239	280	17852	323	21947
195	10784	238	14324	281	17912	324	22040
196	10864	239	14409	282	17972	325	22134
197	10943	240	14494	283	18032	326	22228
198	11023	241	14580	284	18092	327	22322
199	11102	242	14665	285	18152	328	22415
200	11182	243	14752	286	18212	329	22509
201	11262	244	14837	287	18272	330	22603
202	11343	245	14923	288	18333	331	22697
203	11423	246	15009	289	18393	332	22792
204	11504	247	15096	290	18453	333	22886
205	11584	248	15182	291	18513	334	22980
206	11665	249	15268	292	18573	335	23074
207	11746	250	15355	293	18633	336	23169
208	11827	251	15442	294	18693	337	23263
209	11908	252	15528	295	18753	338	23358
210	11990	253	15615	296	18813	339	23453
211	12071	254	15702	297	18873	340	23547
212	12153	255	15789	298	18933	341	23642
213	12235	256	15876	299	19000	342	23737
214	12317	257	15963	300	19060	343	23832
215	12399	258	16051	301	19120	344	23927
216	12481	259	16139	302	19180	345	24022
217	12563	260	16226	303	19240	346	24117
218	12646	261	16314	304	19300	347	24212
219	12729	262	16402	305	19360	348	24307
220	12811	263	16490	306	19420	349	24403
221	12894	264	16578	307	19480	350	24498
222	12977	265	16666	308	19540	351	24593
223	13060	266	16755	309	19600	352	24689
224	13144	267	16843	310	19660	353	24784
225	13227	268	16932	311	19720	354	24880
226	13311	269	17020	312	19780	355	24976
227	13395	270	17109	313	19840	356	25071
228	13478	271	17198	314	19900	357	25167
229	13562	272	17287	315	19960	358	25263
230	13646	273	17376	316	20020	359	25359
231	13731	274	17465	317	20080	360	25455

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
381	25351	391	28457	421	31403	451	34378
382	25647	392	28554	422	31502	452	34577
383	25743	393	28652	423	31600	453	34776
384	25839	394	28750	424	31699	454	34975
385	25936	395	28848	425	31798	455	35174
386	26032	396	28955	426	31897	456	35374
387	26128	397	29043	427	31996	457	35573
388	26225	398	29141	428	32095	458	35773
389	26321	399	29239	429	32194	459	35972
390	26418	400	29337	430	32293	460	36172
391	26514	401	29435	431	32392	461	36371
392	26611	402	29533	432	32491	462	36571
393	26708	403	29631	433	32590	463	36771
394	26805	404	29729	434	32689	464	36971
395	26901	405	29827	435	32788	465	37170
396	26998	406	29926	436	32887	466	37370
397	27095	407	30024	437	32987	467	37570
398	27192	408	30122	438	33086	468	37770
399	27289	409	30220	439	33185	469	37970
400	27386	410	30319	440	33284	470	38170
401	27483	411	30417	441	33384	471	38370
402	27580	412	30516	442	33483	472	38570
403	27678	413	30614	443	33582	473	38770
404	27775	414	30712	444	33682	474	38970
405	27872	415	30811	445	33781	475	39170
406	27969	416	30910	446	33880	476	39370
407	28067	417	31008	447	33980	477	39570
408	28164	418	31107	448	34079	478	39770
409	28262	419	31205	449	34179	479	39970
410	28359	420	31304	450	34278	480	40170

TABLE II.—LENGTHS OF SEMI ELLIPTIC ARCS
(J. C. Trautwine,)*
(SPAN 1).

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
02	1.003	045	1.014	07	1.029	085	1.046
025	1.004	05	1.017	075	1.032	100	1.051
03	1.006	055	1.020	08	1.036	105	1.055
035	1.008	06	1.023	085	1.039	110	1.059
04	1.011	065	1.026	09	1.043	115	1.063

* See Introduction, ante, p. 7.

Height.	Length	Height	Length.	Height	Length	Height	Length
120	1.460	220	1.177	315	1.298	410	1.432
125	1.474	225	1.188	320	1.305	415	1.441
130	1.487	230	1.189	325	1.312	420	1.449
135	1.498	235	1.196	330	1.319	425	1.456
140	1.509	240	1.202	335	1.325	430	1.464
145	1.519	245	1.207	340	1.332	435	1.471
150	1.529	250	1.213	345	1.339	440	1.479
155	1.538	255	1.219	350	1.346	445	1.486
160	1.547	260	1.226	355	1.353	450	1.494
165	1.555	265	1.233	360	1.361	455	1.501
170	1.563	270	1.239	365	1.368	460	1.509
175	1.571	275	1.245	370	1.375	465	1.517
180	1.579	280	1.252	375	1.382	470	1.524
185	1.587	285	1.259	380	1.390	475	1.532
190	1.594	290	1.265	385	1.397	480	1.540
195	1.602	295	1.272	390	1.404	485	1.547
200	1.609	300	1.279	395	1.412	490	1.555
205	1.616	305	1.285	400	1.419	495	1.563
210	1.623	310	1.292	405	1.426	500	1.571
215	1.630						

MEASUREMENT OF SURFACES AND SOLIDS.

Plane Surfaces.

The area of a triangle is equal to half the product of its base by the perpendicular height.

The area of a parallelogram is equal to the product of its length by the height.

The area of a trapezoid (a parallel-sided figure of four sides having two sides not parallel) is equal to the product of half the sum of the parallel sides by the distance between them.

The area of any quadrilateral or four-sided figure, is found by dividing the figure into two triangles, the sum of the areas of which is the area of the quadrilateral.

The area of a square or a rhombus (an oblique-angled equal-sided parallelogram) is equal to half the product of its diagonals.

The area of a polygon or many-sided figure is found by dividing the figure into triangles and trapezoids; the sum of the areas of these is the area of the figure.

The area of a regular polygon is half the product found

multiplying the length of the side by the number of sides and by the perpendicular from the centre to one of the sides. In Table 12, columns 3 and 4 respectively are the lengths of the perpendiculars and the areas of the figures, when the length of the side is equal to 1; also the areas of polygons having an even number of sides, when the width across, between parallel sides (or twice the perpendicular length),

TABLE 12.—REGULAR POLYGONS.

Designation of Polygon.	Number of Sides.	Perpendicular. (Side = 1.)	Area. (Side = 1.)	Area. (Width across = 1.)
1.	2.	3.	4.	5.
Equilateral triangle.	3	0·2887	0·4330	...
Square	4	0·5000	1·0000	1·0000
Pentagon	5	0·6882	1·7205	...
Hexagon	6	0·8660	2·5981	0·8661
Heptagon	7	1·0383	3·6339	...
Octagon	8	1·2071	4·8284	0·3284
Nonagon	9	1·3737	6·1818	...
Decagon	10	1·5388	7·6942	0·8123
Undecagon	11	1·7028	9·3656	...
Dodecagon	12	1·8660	11·1962	0·8082
Circle	infinite	infinite	infinite	0·7854

is equal to 1. A line is added to the table showing the relation of the circle as a polygon having an indefinitely great number of sides.

When the length of the side is other than 1, the perpendiculars and areas are to be calculated by squaring the given value of the side and multiplying the square by the corresponding coefficient in the table: column 3 for the perpendicular, column 4 for the area.

When the width across is other than 1, the area is to be calculated by squaring the value of the given width and multiplying the square by the corresponding coefficient in column 5.

A Regular Polygon may be inscribed in a circle. To supply a means of dividing the circumference of a circle into any number of equal parts, with a view to inscription of a polygon, the annexed tablet of angles at the centre subtended by the sides of polygons, expressed in degrees, is of general utility. Set off round the centre of the circle a succession of angles by means of the protractor, equal to the angle in the table to a given number of sides. The radii so drawn divide the

cumference into the same number of parts. The triangles thus formed are the elementary triangles of the polygon.

TABLE 13.—POLYGONAL ANGLES AT THE CENTRE.

Number of Sides of Polygon	Elementary Angle at Centre	Number of Sides of Polygon	Elementary Angle at Centre
Sides.	Degrees.	Sides.	Degrees.
3	120	12	30
4	90	13	$27\frac{2}{3}$
5	72	14	$25\frac{1}{2}$
6	60	15	24
7	$51\frac{3}{4}$	16	$22\frac{1}{2}$
8	45	17	$21\frac{1}{3}$
9	40	18	20
10	36	19	19 (exactly $18\frac{1}{2}$)
11	$32\frac{2}{3}$	20	18

Circles.

The circumference of a circle is 3.1416 times the diameter, or, approximately, $3\frac{1}{2}$ times. Or, the diameter is to the circumference as 7 to 22, approximately; or as 113 to 355. Trigonometrically, the circle is divisible into 360 degrees.

When the *diameter* is 1, the area is equal to .7854, or approximately $4\text{-}5\text{ths}$. The area of a circle of a given diameter is found by multiplying the square of the diameter by .7854.

The length of an arc of a circle is found by multiplying the number of degrees in the arc by the radius, and by .01745. Or, approximately, by subtracting the chord of the arc from eight times the chord of half the arc, and taking one-third of the remainder.

The area of a sector of a circle is equal to the product of half the length of the arc of the sector by the radius. Or, multiply the number of degrees in the arc by the square of the radius and by .008727.

The area of a segment of a circle. Find the area of the sector which has the same arc as the segment, also the area of the triangle formed by the radial sides of the sector and the chord of the arc. The difference or the sum of these areas is the area of the segment, according as it is less or greater than a semicircle.

The area of a ring. Multiply the sum of the outer and inner diameters by their difference and by .7854.

The area of a zone of a circle. Find the areas of the

segments cut off, and subtract the sum of these areas from the area of the whole circle, to give the area of the zone.

The side of a square equal in area to a given circle is equal to the product of the diameter by .8862.

The side of a square inscribed in a circle is equal to the product of the diameter by .7071.

The area of an inscribed square is equal to the product of the area of the circle by .6366.

The diameter of a circle equal in area to a given square is equal to the product of the side of the square by 1.1284, or 1 $\frac{1}{4}$ approximately.

The diameter of a circumscribing circle is equal to the product of the side of the given square by 1.4142.

The area of a circumscribing circle is equal to the product of the area of the given square by 1.5708.

Ellipse.

The circumference of an ellipse is equal to the product of the square root of half the sum of the squares of the two axes by 3.1416.

This rule is approximate. Mr. Trautwine proposes the following formula for the circumference of an ellipse, as more nearly exact, and sufficiently so for ordinary purposes. When the longer axis, D , is not more than five times the length of the shorter axis, d ,

$$\text{Circumference} = 3.1416 \sqrt{\frac{D^2 + d^2}{2} - \frac{(D - d)^2}{8.8}} \quad (1)$$

When the longer axis is more than five lengths of the shorter axis, the divisor 8.8 under the sign is to be replaced by the following divisors:—

				Divisor.
When the longer axis is 6 times the shorter				9
"	"	7	"	9.2
"	"	8	"	9.3
"	"	9	"	9.35
"	"	10	"	9.4
"	"	12	"	9.5
"	"	14	"	9.6
"	"	16	"	9.68
"	"	18	"	9.75
"	"	20	"	9.8
"	"	25	"	9.87
"	"	30	"	9.92
"	"	40	"	9.98
"	"	50	"	10.00

The area of an ellipse is equal to the product of the two axes by .7854.

The area of a segment of an ellipse, the base of which is parallel to one of the axes of the ellipse. Divide the height of the segment by the axis of which it is a part, and find the area of a circular segment, in a table of circular segments, of which the height is equal to the quotient; multiply the area thus found by the two axes of the ellipse successively; the product is the area.

Curvilinear Figures.

The area of any curvilinear figure bounded at the ends by parallel straight lines by Simpson's rule. Divide the length of the figure into any even number of equal parts, at the common distance D apart, and draw ordinates through the points of division, to touch the boundary lines. Add together the first and last ordinates, and call the sum A; add together the even ordinates, and call the sum B; add together the odd ordinates, except the first and last, and call the sum C. Then,

$$\text{area of the figure} = \frac{A + 4B + 2C}{3} \times D \quad (2)$$

2nd Method. Divide the figure into any sufficient number, n , of equal parts; add together the first and last ordinates, making the sum A; add together all the intermediate ordinates, making the sum B. Putting L for the length of the figure. Then,

$$\text{area of the figure} = \frac{A + 2B}{2n} \times L \quad (3)$$

3rd Method.—Divide the figure into a sufficient number of equal parts, as before. Add together the mean depths of the several divisions, and divide the sum by the number of divisions, to give the average depth; multiply the average depth by the total length, to give the area.

The figure may, otherwise, be divided into two half parts, one at each end, and a number of whole parts intermediately. The sum of the ordinates, excepting the extreme ordinates, divided by the number of them, gives the average depth, and the product of this by the length, gives the area.

The figures may be bounded at the ends by curves or angles. In this case, the extreme ordinates become nothing.

Solids.

There are five species of regular solids, bounded by regular polygons, of which particulars are given in the annexed table:—

TABLE 14.—REGULAR SOLIDS.

Designation of Solid. 1	Number and Designation of Sides. 2	Superficial Area (Edge = 1) 3	Contents (Edge = 1) 4
Tetrahedron .	4 equilateral triangles .	1.7320	0.1178
Hexahedron, } or Cube }	6 squares	6.0000	1.0000
Octahedron .	8 equilateral triangles .	3.4641	0.4714
Dodecahedron	12 pentagons	20.6458	7.6631
Icosahedron .	20 equilateral triangles .	8.6603	2.1817

Regular solids may be circumscribed by spheres ; and spheres may be inscribed in regular solids.

To find the total area of surface of a regular solid, multiply the square of the length of the edge by the tabular number given in column 3 of the table.

To find the contents of a regular solid, multiply the cube of the length of the edge by the tabular number in column 4 of the table.

The four leading solids are the cube, the cylinder, the sphere, and the cone. A cubic foot contains

- 1,728 cubic inches, or
- 2,200 cylindrical inches, or
- 3,300 spherical inches, or
- 6,600 conical inches.

These values supply an easy practical rule for finding, by proportion, the capacities of the “three round bodies.”

The surface of a cylinder, or of a prism, is equal to the product of the perimeter of one end by the height ; plus twice the area of one end.

The cubic content of a cylinder, or of a prism, is equal to the product of the area of the base by the length or height of the cylinder.

The surface of a sphere is equal to the product of the square of the diameter by 3.1416.

It is equal to four times the area of one of its great circles.

It is equal to the convex surface of its circumscribing cylinder.

The surfaces of spheres are to each other as the squares of their diameters.

The curve surface of a segment, or a zone of a sphere, equal to the product of the diameter of the sphere by height of the segment or zone, and by 3.1416. The

THE FILE SEGMENTS, CONIC SECTIONS,

- The second method is not exact, but
- as to exactness for arcs less than one-f

is a curve such that the sum of the distances from two fixed points is constant.

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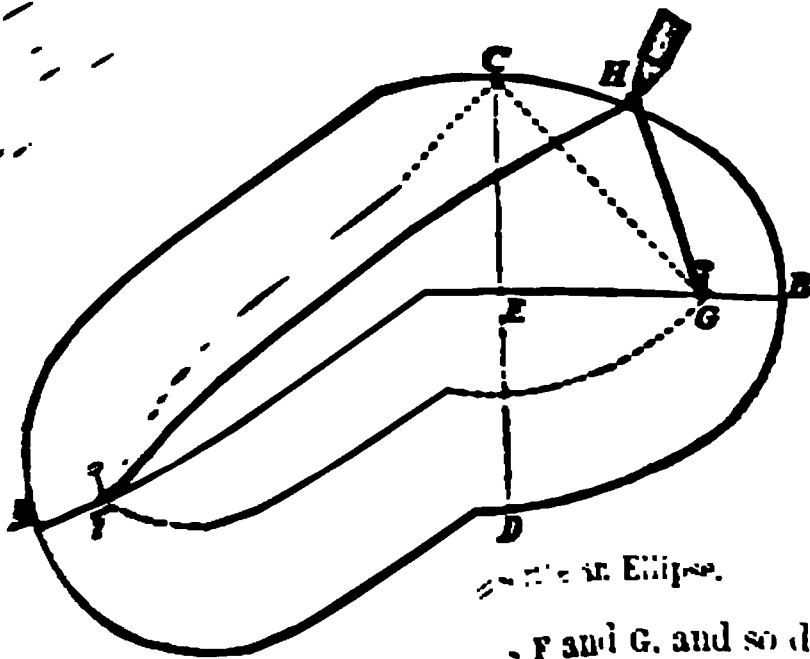
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the transverse axis, fig. 4 at

the perpendicular DE, making CD

the conjugate axis. From D or E, v



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$$S = \frac{2n^3 + 3n^2}{6}$$

number of spheres = 10, the number of spheres is 10.

$$10 \div 6 = 385.$$

number of spheres
10, the number
 $\div 6 = 385$.

The value n expresses a^r of the base. If, for e^r is, by the formula, (r

2. On a triangle.

+ 2)

ELLIPSE.

3rd Method (approximate). With arcs of two radii, fig. 5. lay down the axes AB and CD, and set off OA and OC equal to the difference of the lengths of the axes. Draw ac and set off half of ac to d and oe equal to Od. Draw di, and parallels intersecting at m. From the centres m and i, describe arcs through c and d; and e, de-

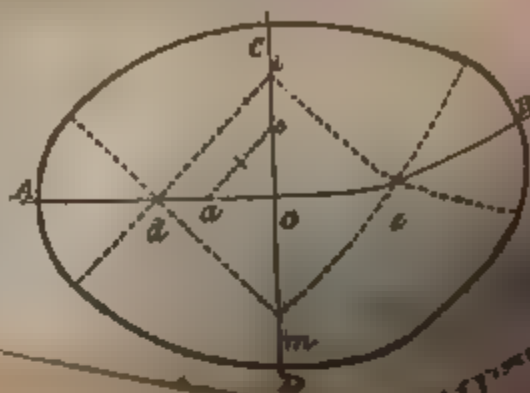


Fig. 2. To describe a Circular Arc through three points. Divide the arcs through the given points into equal parts, at 1, 2, 3, &c., and from D

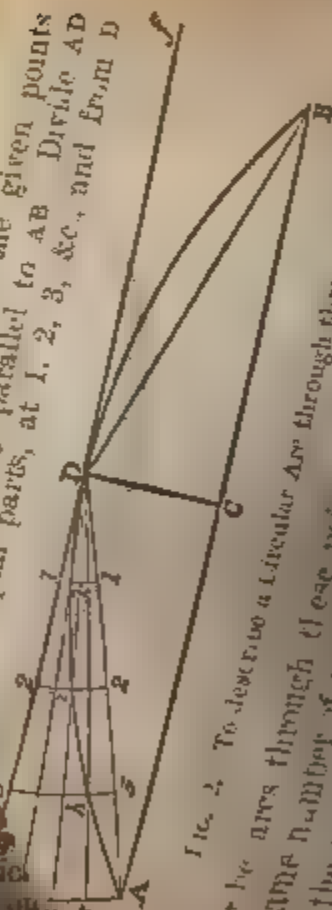


Fig. 3. To describe a Circular Arc through three points. Divide the arcs through the given points into equal parts, at 1, 2, 3, &c., and from D draw straight lines from the points of division. The intersections of these lines with the arcs 1, 2, 3, &c., are points in the circle.

The surface of a frustum of a cone or a pyramid is equal to the product of the sum of the perimeters of the ends by half the slant height, plus the areas of the ends.

The content of a frustum of a cone or a pyramid is found by adding together the areas of the ends and the mean proportional between them (the square root of their product), and multiplying the sum by one-third of the perpendicular height.

Or, in the case of a conical frustum, add together the squares of the diameters and the product of the diameters and multiply the sum by .7854, and by one-third of the height.

The content of a wedge is found by adding together twice the length of the base and the length of the edge, and multiplying the sum by the breadth of the base, and by one-sixth of the height.

The content of a prismoid (a solid having three or more inclined sides, and similar parallel ends) is found by adding together the areas of the ends, and four times the intermediate sectional area equally distant from the ends; and multiplying the sum by one-sixth of the length.

The content of an irregular solid may be found by dividing it into parts measurable by the ordinary rules, and adding together the contents of them; the sum is the content of the solid.

Piles of equal spheres or balls. Ranged usually in pyramidal piles, on a square or a triangular base; or in oblong piles on a rectangular base.

1. *To find the number of balls in a pile on a square base.* Let n = the number of horizontal strata or layers of spheres in the piles, comprising the highest stratum, which consists of one sphere. The number, S , of spheres is

$$S = \frac{2n^3 + 3n^2 + n}{6} \quad (1)$$

The value n expresses also the number of spheres in one side of the base. If, for example, $n = 10$, the number of balls is, by the formula, $(2,000 + 300 + 10) \div 6 = 385$.

2. *On a triangular base.*

$$S = \frac{n(n+1)(n+2)}{6} \quad (2)$$

If n is equal to 10, S is equal to 220.

3. *Oblong pile on a rectangular base.* The uppermost stratum is a row of balls, say m in number,

$$S = \frac{n(n+1)(3m+2n)}{6} \quad (3)$$

Supposing m and n each equal to 10, S is equal to 880.

DESCRIPTION OF CIRCULAR SEGMENTS, CONIC SECTIONS AND CYCLOIDS.

To describe a Circle passing through three given points, when the Centre is not available. From the extreme points A, B, fig. 1, as centres describe arcs AH, BG. Through the third point C draw AE, BF. Divide AF and BE into any

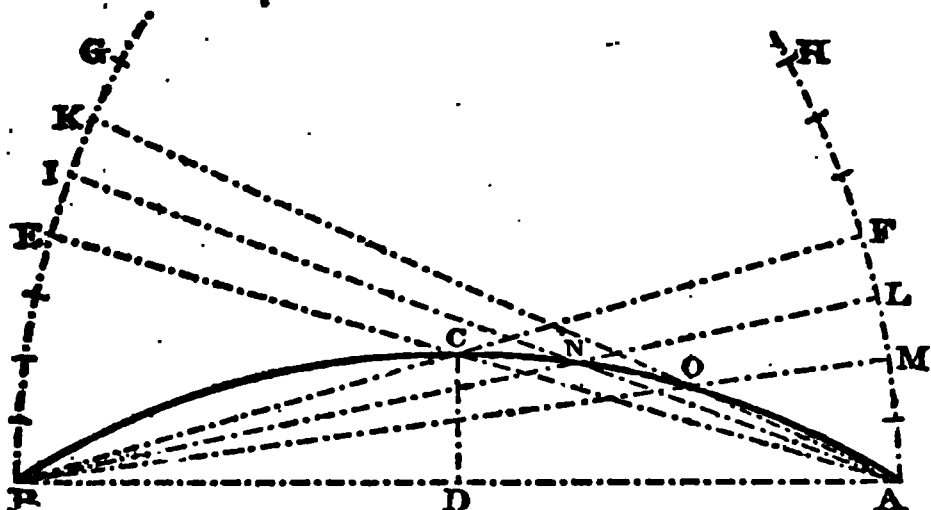


FIG. 1.—To describe a Circular Arc through three points.

convenient number of equal parts, and set off a series of equal parts of the same length on the upper portions of the arcs, beyond the points E, F. Draw straight lines BL, BM, &c., to the divisions in AF; and AI, AK, &c., to the division in EG. The successive intersections at N, O, &c., of these lines, are points in the circle required, between the given points A and C, which may be traced in accordingly. Similarly, the remaining part of the curve may be described.

2nd Method. Let A, B, C, fig. 2, be the given points. Draw AB, AD, and DB; and ef parallel to AB. Divide AD into a number of equal parts, at 1, 2, 3, &c., and from D

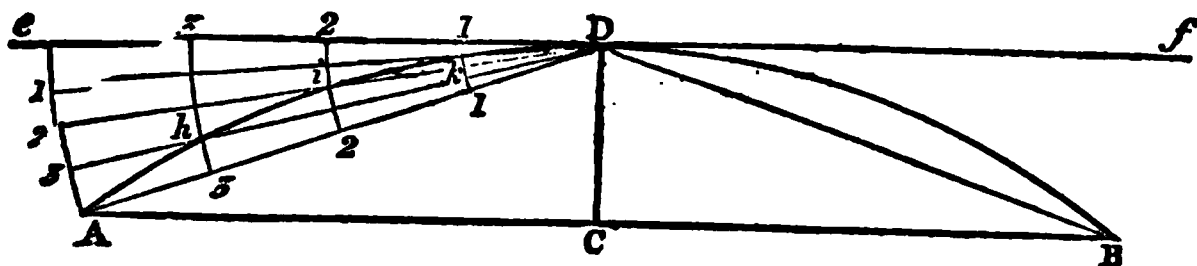


FIG. 2.—To describe a Circular Arc through three points.

describe arcs through these points. Divide the arc Ae into the same number of equal parts, and draw straight lines from D to the points of division. The intersections of these successively with the arcs 1, 2, 3, &c., are points in the

Note.—The second method is not exact, but it is sufficiently near to exactness for area less than one-fourth of a circle.

The Ellipse is a Curve such that the sum of the distances of any point in the curve from two fixed points or foci, is constant.

To describe an Ellipse, when the length and width are given. On the centre

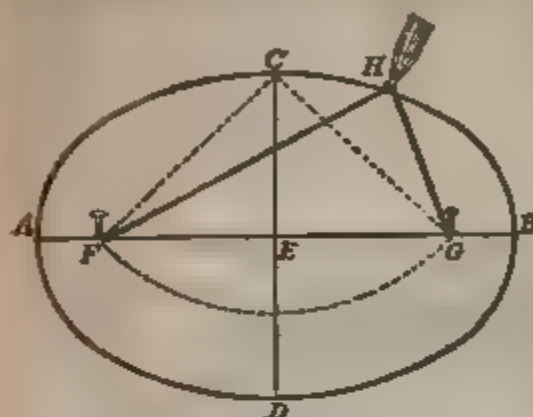


FIG. 3. To describe an Ellipse.

fig. 3, with AE as radius, cut the axis AB at F and G, the foci. Fix a couple of pins into the axis at F and G, and loop a thread or cord upon them equal in length to the axis AB, so as, when stretched, to reach to the extremity C of the conjugate axis. With a pencil or draw-point inside the cord, as at H, guide the pencil in ten-

sion about the pins F and G, and so describe the ellipse.

2nd Method. Bisect the transverse axis, fig. 4 at C, and through C draw the perpendicular DE, making CD and CE each equal to half the conjugate axis. From D or E, with the



Fig. 4. To describe an Ellipse.

radius AC cut the transverse axis at F, F', for the foci. Divide AC into any number of parts at 1, 2, 3, &c. With the radius A1, on F and F' as centres, describe arcs; and with the radius B1 on the same centres, cut these arcs, as shown. Repeat the operation for the other points of division of the transverse axis. The series of intersections thus made are points in the curve, through which the curve may be traced.

3rd Method (approximate). With arcs of two radii, fig. 5. Lay down the axes AB and CD, and set off oa and oc equal to the difference of the lengths of the axes. Draw ac and set off half of ac to d , and oc equal to od . Draw di , ei , and parallels intersecting at m . From the centres m and i , describe arcs through C and D ; and from d and e , describe arcs through A and B . The four arcs form the ellipse.

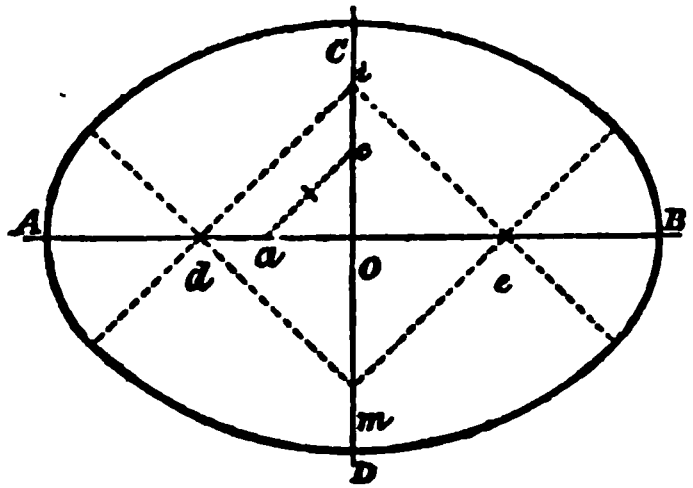


FIG. 5.—To describe an Ellipse.

Note. — This method is applicable when the conjugate axis is at least two-thirds of the transverse axis.

4th Method (approximate). With arcs of three radii, fig. 6.

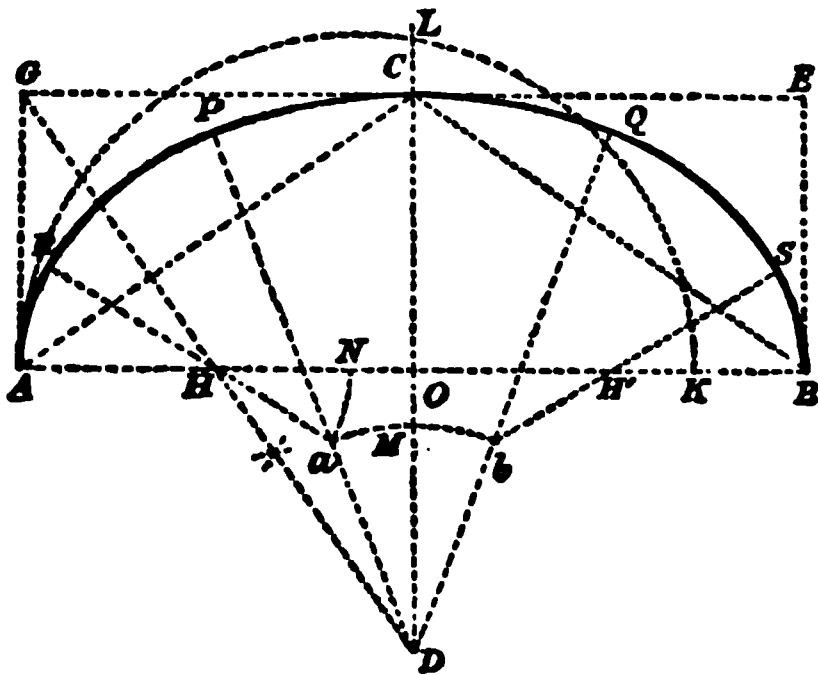


FIG. 6.—To describe an Ellipse.

On the transverse axis AB, draw the rectangle BG, on the height OC , of the semi-conjugate axis. To the diagonal AC draw the perpendicular GHD; set off OK equal to OC , and describe a semicircle on AK , and produce OC to L . Set off OM equal CL , and on D describe an arc with the radius DM . On A with radius OL , cut this arc at A . The five centres D, a, b, H, H' , are found, from which the arcs are described to form the ellipse.

Note.—This process works well for nearly all proportions of ellipses.

The parabola is a curve such, that the distance of any point in the curve from a fixed point, the focus, is equal to its distance from a straight line, the directrix.

To describe a Parabola, when an absciss and its ordinate

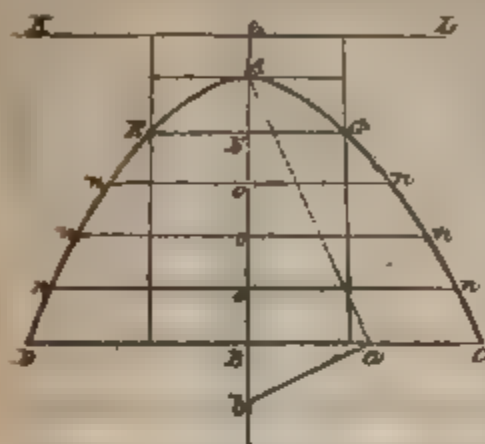


FIG. 7.—To describe a Parabola.

or the height and the base are given. Bisect the given ordinate BC, fig. 7, at a, draw Aa , and then ab perpendicular to it, meeting the axis at b . Set off Aa and Ab , each equal to Bb , and draw KL at right angles to the axis. Then KL is the directrix and F is the focus. Through F and any number of points $a, c, \&c.$, in the axis, draw double ordinates $aa', cc', \&c.$, and on the center F , with the radii $Fa, Fc, \&c.$, cut the respective ordinates

at $E, G, n, n', \&c.$ The curve is traced through these points of intersection.

2nd Method. Place a straight-edge to the directrix EN , fig. 8,

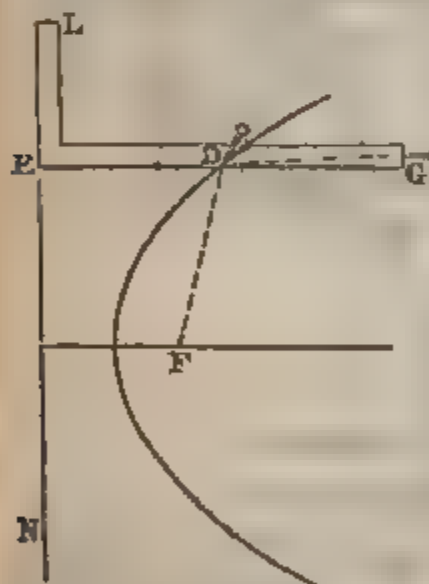


FIG. 8.—To describe a Parabola.

and apply to it a square LEG . Fasten to the end G one end of a thread or cord, shown in dot lining, equal in length to the edge EG , and attach the other end to the focus F . Slide the square along the straight-edge, holding the cord taut against the edge of the square by a drawpoint or pencil D , by which the curve is described.

3rd Method. Through the vertex A , fig. 9, draw EF parallel to CD the base, and through C and D draw CE and DF parallel to the axis AB . Divide BC and BD into any number of equal parts at $a, b, \&c.$, and divide CE and DF into the same number of equal parts. Through the

points a, b, c, d , in the base CD , draw perpendiculars, and through a, b, c, d in CE and DF draw lines to the vertex A , cutting the perpendiculars at e, f, g, h . These are points in the curve, which may be traced through them.

The nature of the parabola is such that the abscissæ vary in length as the squares of the ordinates. Inversely, the ordinates vary as the square roots of the abscissæ. By means of these

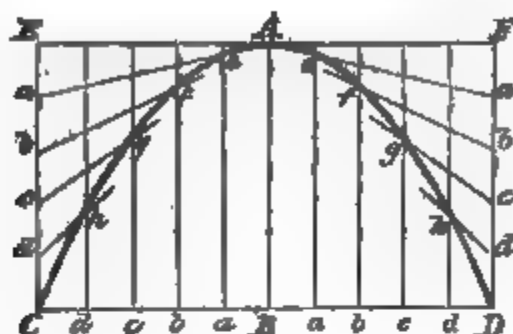


FIG. 9.—To describe a Parabola.

relations any number of points in the curve may be determined, and the curve constructed.

The hyperbola is a curve such that the difference of the distances of any point in the curve from two fixed points, the foci, is equal to a constant, the transverse axis. The vertices A, B, fig. 10, of opposite hyperbolas, are the heads of the

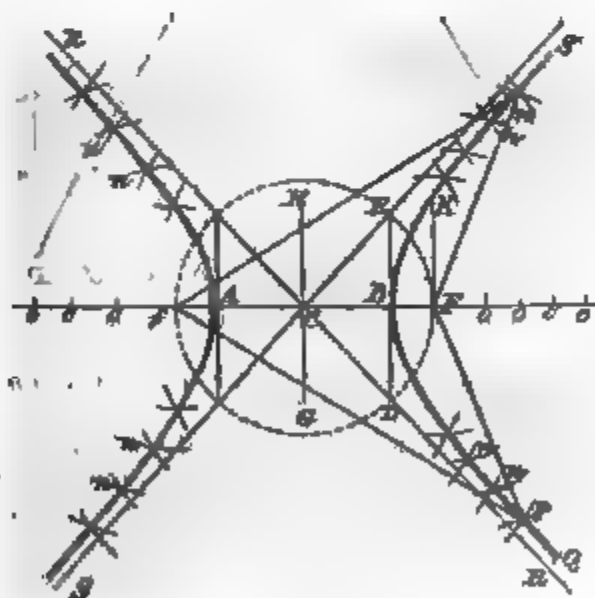


FIG. 10.—To describe a Hyperbola.

curves, in their axial lines. The transverse axis AB is the distance between the vertices. The conjugate axis GH passes through the centre C, at right angles to the transverse axis.

To describe a Hyperbola. Let the ends of two threads fPQ , rPQ , fig 10, be fastened at the points f and r , and passed through a small bead or pin P , and knotted together at Q . Take hold of Q and draw the threads taut, move the bead along the threads, and the point P will describe the curve.

2nd Method. When the base CD , height AB , and transverse axis AA' , fig 11, are given. Divide the base CD into a number of equal parts on each side of the axis at a , b , &c.; and divide the parallels CE , DF , into the same number of equal parts at a , b , &c. From the points a , b , &c., in the base, draw lines to A' , and from the points a , b , &c., in the verticals, draw

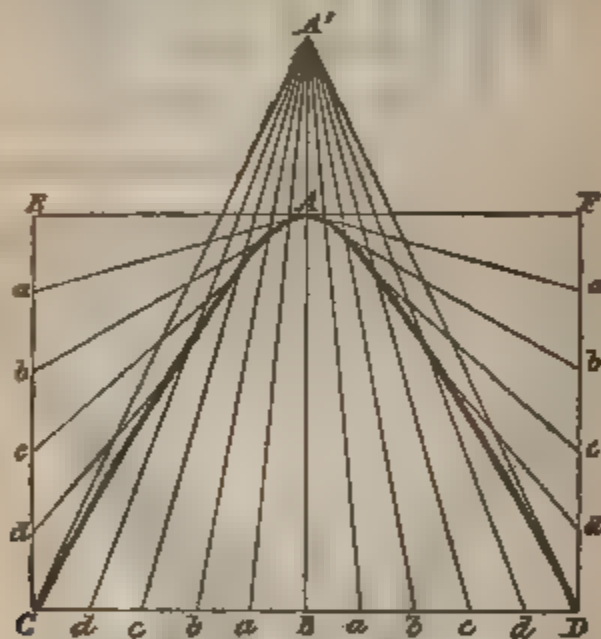


FIG. 11. To describe a Hyperbola.

lines to A , cutting the respective lines from the base. Trace the curve through the intersections.

To describe a Right-angled Hyperbola, given a point in the curve. Let E , fig. 12, be a point in the curve, of which AE and AC , at right angles to each other, are the asymptotes. Draw the parallels DE and DC to complete the rectangle $ADCE$. Set off dd' on the base line equal to AD , and draw the vertical dd' . Bisect AC at b , and draw bb' parallel to the base; the point of intersection, e , is a point in the curve. Similarly bisecting Ab at c , and Ac at a ; doubling Ad to d' , and Ad' to d'' , and completing the rectangles $d'ce$ and $d''ce''$, and again bisecting and doubling, the points e' and e'' , and e''' in the curve are found. By a like process of dividing and multiplying

versely, any additional number of points may be found, and the curve may be traced through the points.

This curve possesses the useful property that the elementary rectangles are equal in area.

The cycloid ADB , fig. 13, is the curved path described by

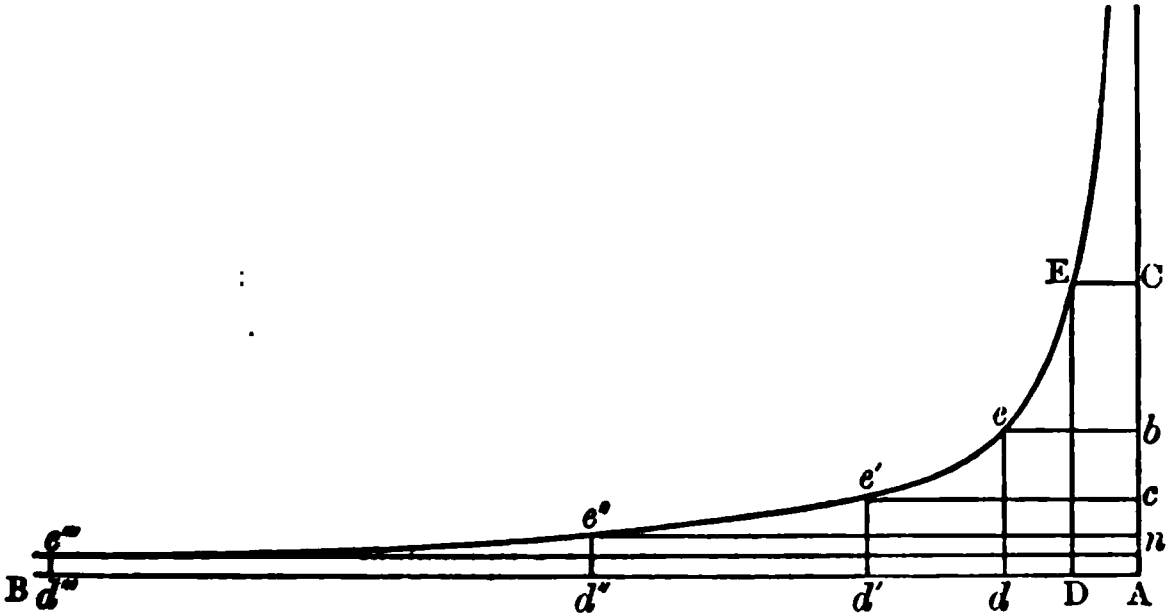


FIG. 12.—To describe a Right-Angled Hyperbola.

any point D in the circumference of a wheel or a circle DGC which rolls along a straight line. The base AB for a complete

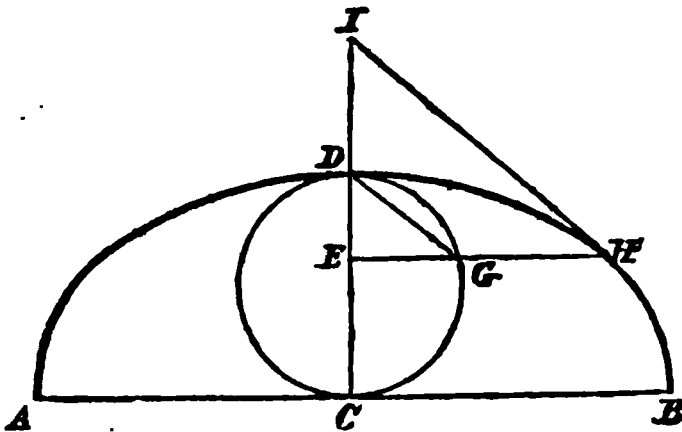


FIG. 13.—Cycloid.

revolution of the wheel, is equal in length to the circumference of the circle; the length of the curve is equal to four times the diameter of the circle; the area of the cycloid, $ADBA$, is equal to three times the area of the circle.

The exterior epicycloid ADB , fig. 14, is the curve described by any point in the circumference of one circle, DC , rolling over another circle, ACB , on the outside of the circumference.

The hypocycloid, or interior epicycloid, ADB , fig. 15, is

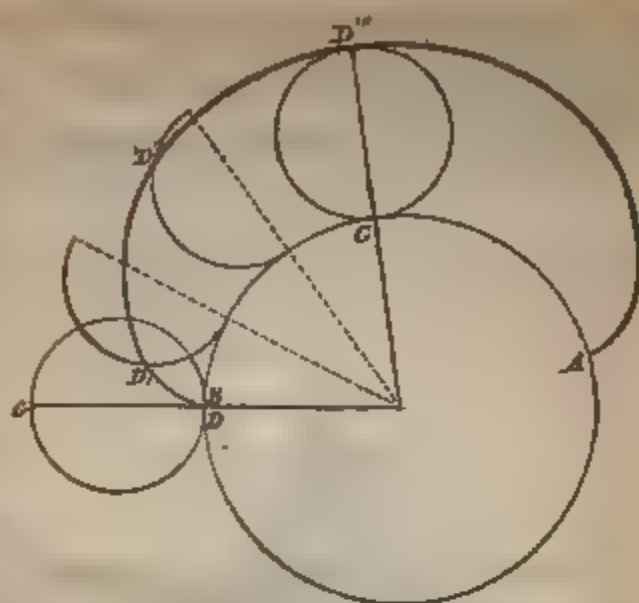


FIG. 14.~ Exterior Epicycloid.

curve ADB described by a point in the circumference of a circle rolling on the inside of the circumference of another

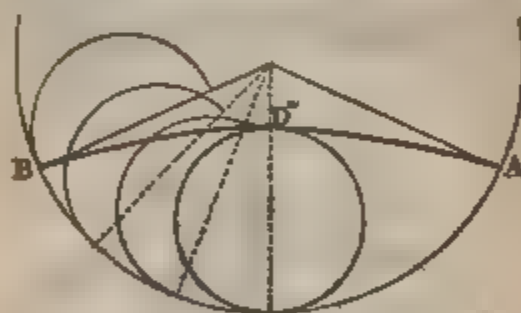


FIG. 15. Interior Epicycloid

circle. When the diameter of the rolling circle is equal to half the diameter of the fixed circle, the curve becomes a straight line, or a diameter of the fixed circle.

WEIGHTS AND MEASURES.

THE yard and the pound are the units of English measure and weight.

The imperial standard yard is a solid square bar, 38 inches long, 1 inch square, of bronze or gun-metal, deposited in the Standards Department of the Board of Trade. The length of the yard is defined by lines inscribed on two gold plugs inserted near each end of the bar.

The imperial standard pound is a cylinder of platinum, nearly 1·36 inches in height, and 1·15 inches in diameter, having a groove or channel round it, near the top, by which it may be lifted.

Copies of the standard yard and the standard pound have been deposited in the Royal Mint and the Greenwich Observatory; copies have been immured in the New Palace at Westminster; and copies have been delivered to the Royal Society of London.

The unit or standard measure of capacity, for liquids as for dry goods, is the gallon, capable of containing ten imperial standard pounds weight of distilled water weighed in air against brass weights, at the temperature of 62° F., with the barometer at 30 inches. The standard measure is cylindrical, on a plane base, and the height is equal to the diameter.

The standard bushel, as a measure of capacity, is cylindrical, about 17·8 inches in diameter, with a plane base; the depth is half the diameter, about 8·9 inches. It has a capacity equal to 8 gallons.

In using an imperial measure of capacity, it is not to be heaped; but is either to be stricken with a round stick or cylindrical roller; or, if the article cannot be conveniently stricken, it is to be filled in all parts as nearly to the level of the brim as the size and shape of the article admits.

LIST OF GAUGES DEPOSITED AT THE STANDARDS OFFICE BY SIR JOSEPH WHITWORTH.

1 set, External plane gauges, containing 91 sizes, from ·01 to 0·1, rising by ·001 inch.

6 sets, Internal and External Cylindrical gauges, containing the following fractional sizes:—

1 set containing 15 gauges from $\frac{1}{8}$ inch to 1 inch, increasing by $\frac{1}{16}$ inch.

1 " " 8 " " $1\frac{1}{8}$ inches to 2 inches, increasing by $\frac{1}{8}$ inch.

1 set containing 8 gauges from $2\frac{1}{2}$ inches to 3 inches, increasing by $\frac{1}{8}$ inch.

1 " " 8 " " $3\frac{1}{2}$ inches to 4 inches, increasing by $\frac{1}{8}$ inch.

1 " " 4 " " $4\frac{1}{2}$ inches to 5 inches, increasing by $\frac{1}{4}$ inch.

1 " " 4 " " $5\frac{1}{2}$ inches to 6 inches, increasing by $\frac{1}{4}$ inch.

6 sets, containing the following decimal sizes:

1 set containing 15 gauges, sizes, 0.10, 0.15, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9 inches.

1 " " 8 " " 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9 inches.

1 " " 8 " " 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9 inches.

1 " " 4 " " 4.2, 4.4, 4.6, 4.8 inches.

1 " " 4 " " 5.2, 5.4, 5.6, 5.8 inches.

From 6 inches to 2 inches inclusive, the gauges are made of cast iron; and below 2 inches they are made of steel.

The above collection of gauges is denominated as follows:

(1.) Whitworth's External Cylindrical Gauges: external diameters in terms of the inch.

15 gauges from $\frac{1}{16}$ inch to 1 inch, increasing by sixteenth of an inch.

24 gauges from $1\frac{1}{8}$ inches to 4 inches, increasing by eighths of an inch.

8 gauges from $4\frac{1}{4}$ inches to 6 inches, increasing by quarters of an inch.

19 gauges from 0.1 inch to 1 inch, increasing by five one hundredths of an inch.

30 gauges from 1.1 inches to 4 inches, increasing by tenths of an inch.

10 gauges from 1.2 inches to 6 inches, increasing by fifths of an inch.

(2.) Whitworth's Internal Cylindrical Gauges: internal diameters in terms of the inch—a repetition of section (1) preceding.

(3.) Whitworth's External Plane Gauges, thickness in terms of the inch.

91 gauges from .01 inch to 0.1 inch, increasing by thousandths of an inch.

TABLE 15.—ENGLISH MEASURES OF LENGTH.

		French Equivalents.
12 lines	} 1 inch	25·4 millimetres.
72 points		
1000 mils		
7·92 inches	1 link	·2012 metre.
12 inches	1 foot	·3048 metre.
3 feet	1 yard	·91439 „
6 feet	1 fathom	1·82878 „
5½ yards	1 rod, pole, or perch	5·02915 „
100 links	} 1 chain	20·1166 „
66 feet		
220 yards	} 1 furlong	{ 201·1662 metres. 0·20117 kilometre.
40 poles		
10 chains		
8 furlongs	} 1 mile	{ 1609·3296 metres. 1·60933 kilometres.
80 chains		
1,760 yards		
5,280 feet		
1·1515 miles	} 1 Admiralty knot or nautical mile	} 1·85315 kilometres.
6080 feet		

English Measures of Surface.

TABLE 16.—ORDINARY SUPERFICIAL MEASUREMENT.

1 square inch	{ 645·15 square millimetres. 6·4515 square centimetres.	
144 square inches	} 1 square foot	·0929 square metre.
183·35 circular inches		
9 square feet	1 square yard	·8361 square metre.
100 square feet (for roofing and flooring)	} 1 square	9·2901 square metres.
30¼ square yards		
	{ 1 square pole, rod, or perch	{ 25·292 square metres.
40 square poles	1 rood	{ 1011·696 square metres. 10·1170 ares.
4 roods	} 1 acre*	{ 4046·782 square metres. 40·4678 ares. 4047 hectares.
4840 square yards		
640 acres		
	1 square mile	258·9894 hectares.

* The side of a square acre is equal to 69·57 lineal yards.

English Measures of Volume and Capacity.

TABLE 17. SOLID OR CUBIC MEASURE.

1 cubic inch	.	.	.	16·387 cubic centimetres
1728 cubic inches	}	1 cubic foot	}	28·3153 cubic decimetres.
2200·15 cylindrical inches				·028315 cubic metres
3300·23 spherical inches				
6600·15 conical inches				
27 cubic feet	1 cubic yard	.	.	·764513 cubic metres
1·308 cubic yard	}	.	.	1 cubic metre
31·3156 cubic feet				

TABLE 18.—DRY MEASURE.

2 pints	1 quart	1.1359 litres
4 quarts (277.274 cubic inches)	1 gallon	4.5435 litres
2 gallons	1 peck	9.0869 litres
4 pecks (1.28366 cubic feet)	1 bushel	36.3477 litres
8 bushels	1 quarter	290.782 litres
4 quarters (41.077 cubic feet)	1 chaldron	1.1631 cubic metres
5 quarters	1 load, or way	1.4539 cubic metres
2 loads	1 last	2.9078 cubic metres

Builders' Measurement.

TABLE 19.—LINEAL MEASURE.

12 inches	1 foot
3 feet	1 yard
16½ feet	1 rod

Rubble-walling, in some parts of England, is measured the rod of $16\frac{1}{2}$ feet, by 1 foot high : and the various thicknesses are stated.

TABLE 20. SUPERFICIAL MEASURE.

1 part	1 square inch.
12 parts	1 inch (12 square inches).
12 inches	1 foot.
3 feet	1 yard.
100 feet	1 square.
2721 feet	1 rod.

Brickwork generally is measured by the rod of 272 superficial (not 272½ feet) reduced to 1½ bricks in thick-

But, for engineering works, it is measured by the cubic yard of 27 cubic feet.

Flooring, slating, and tiling, are measured by the square.

Paving, painting, plastering, &c., are measured by the yard.

TABLE 21.—CUBIC MEASURE.

1 third	1 cubic inch.
12 thirds	1 part (12 cubic inches).
12 parts	1 inch (144 cubic inches).
12 inches	1 foot (1728 cubic inches).
27 feet	1 yard.

Excavation, concrete, &c., are measured by the cubic yard.

Masonry, square-sided timber, &c., are measured by the cubic foot.

Timber.

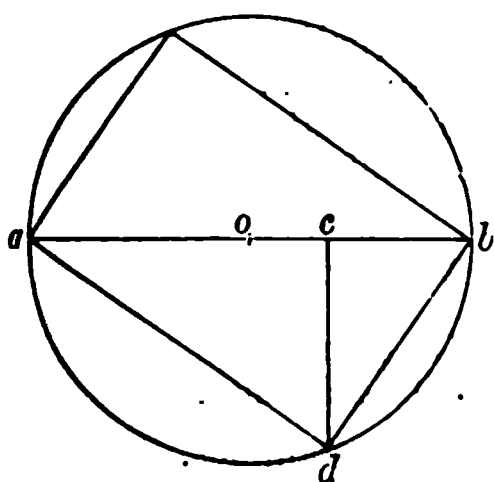


FIG. 16.—To find Strongest Section of Round Tree.

The inscribed square in the section of a round tree gives the maximum of sectional area, but not the maximum of transverse strength. To find the strongest section, draw a diameter $a b$; from the centre o set off $o c$ one-third of the radius $o b$, and draw the perpendicular $c d$. Draw $d b$ and $d a$, and complete the parallelogram. The area of the parallelogram is 6 per cent. less than that of the square section; but it is 9 per cent. stronger.

TABLE 22.—LIQUID MEASURE.

8·665 cubic inches	1 gill or quartern	·1420 litre.
4 gills	1 pint	·5679 litre.
2 pints	1 quart	1·1359 litres.
4 pints	1 pottle	2·2718 litres.
8 pints { (277·274 cubic inches) }	1 gallon	4·5435 litres.
4 quarts { }		
6·2355 gallons	1 cubic foot.	
168·3765 gallons	1 cubic yard.	
220·09 gallons		1 cubic metre.

TABLE 23.—OLD WINE AND SPIRIT MEASURE.

4 gills or quarterns	1 pint.	Imperial Gallons
2 pints	1 quart.	
4 quarts (231·06 cubic inches)	1 gallon	·8333.

31½ gallons	1 barrel	Imperial gallons, — 26·25.
63 gallons } 2 barrels }	1 hogshead	— 52·5.
84 gallons	1 puncheon	— 70.
126 gallons	1 pipe or butt	— 105.
2 pipes	1 tun	— 210.

Wines, spirits, oils, &c., are measured by this scale; but the contents of casks are reckoned in imperial gallons when sold.

TABLE 24.—APOTHECARIES' FLUID MEASURE (ENGLISH).

60 minims (m)	1 fluid drachm (f 3).
8 drachms (water 1·732 cubic inches, 437½ grains)	1 fluid ounce (f 5).
20 ounces	1 pint (o).
80 pints (water, 70,000 grains)	1 gallon (gall.)
4 drachms	1 tablespoonful.
2 ounces (water, 875 grains)	1 wineglassful.
3 ounces	1 teacupful.

TABLE 25.—AVOIRDUPOIS WEIGHT.

1 grain.	·0648 gramme.
27·344 grains	1 drachm . . . 1·7718 grammes.
16 drachms } 437½ grains }	1 ounce . . . 28·3495 grammes.
16 ounces } 7000 grains }	1 pound . . . { 453·5926 grammes. 453·59 kilogrammes.
14 pounds	1 stone . . . 6·3503 kilogrammes.
28 pounds	1 quarter . . . 12·7006 kilogrammes.
4 quarters } 112 pounds }	1 hundredweight 50·8024 kilogrammes.
20 hundredweights } 2240 pounds }	1 ton . . . { 1016·048 kilogrammes. 1·01605 metric ton.

TABLE 26. TROY WEIGHT.

24 grains	1 pennyweight . . . 1·5552 grammes.
20 pennyweights } 480 grains }	1 troy ounce . . . 31·1035 grammes.
12 troy ounces } 5760 grains }	1 troy pound . . . { 373·2419 grammes. 373·24 kilogramme.
25 pounds	1 troy quarter . . . 9·3310 kilogrammes.
1 quarter } 100 pounds }	1 troy hundredweight . . . 37·3242 kilogrammes.

TABLE 27.—COAL WEIGHT (ENGLISH).

14 pounds	. . . 1 stone	. . . 6·3503 kilogrammes.
88 pounds	. . . 1 bushel	. . .
1 sack of 112 pounds	1 hundredweight	50·8024 kilogrammes.
20 hundredweights	1 ton . . .	1·01605 metric ton.
26½ hundredweights	{ 1 chaldron (London) }	. . . 1·3462 metric ton.
53 hundredweights	{ 1 chaldron (Newcastle) }	. . . 2·6924 metric tons.

Sundry bushels of coal.—Cornish, 90 or 94 pounds ; heaped, 101 pounds ; Welsh, 93 pounds ; Newcastle, 80 or 84 pounds ; London, 80 or 84 pounds.

The “colliery ton” is 21 cwt. of 120 lbs. each.

TABLE 28.—HAY AND STRAW WEIGHT (ENGLISH).

1 truss of straw	. . . 36 pounds.
1 load of straw	. . . 11 hundredweights, 64 pounds.
1 truss of old hay	. . . 56 pounds.
1 load of old hay	. . . 18 hundredweights.
1 truss of new hay	. . . 60 pounds.
1 load of new hay	. . . 19 hundredweights, 32 pounds.
1 cubic yard of compact old hay	} 15 stones.

Loose hay, 5 pounds per cubic foot ; ordinarily pressed, as in a stack, 8 pounds ; close pressed, as in a bale, 12 to 14 pounds ; ordinarily pressed, as in a waggon-load, from 450 to 500 cubic feet weigh 1 ton.—*Haswell.*

TABLE 29.—CORN AND FLOUR WEIGHT (ENGLISH).

1 peck, or stone, of flour	. . . 14 pounds
10 pecks	. . . 1 boll . . . 140 „
2 bolls	. . . 1 sack . . . 280 „
14 pecks	. . . 1 barrel . . . 196 „
1 bushel of wheat	. . . 60 „
1 bushel of barley	. . . 47 „
1 bushel of oats	. . . 40 „
80 bushels of corn	. . . 1 last.

Six bushels of wheat should yield one sack of flour.

TABLE 30.—TIMBER MEASURES FOR BUILDING PURPOSES (ENGLISH).

Load of timber, unhewn or rough	. . . . .	40 cubic feet.
Load, hewn or squared	. . . . .	50 cubic feet
		reckoned
		weigh 20

	ins.	ins.	ins.	Weight.
Paving	9	$\times 4\frac{1}{2}$	$\times 1\frac{3}{4}$	5.00 lbs.
Square tiles	$9\frac{3}{4}$	$\times 9\frac{3}{4}$	$\times 1$	5.70 „
do.	6	$\times 6$	$\times 1$	2.16 „

A rod of brickwork is,—

16½ feet \times 16½ feet \times 1½ bricks thick ;
 306 cubic feet, or 11½ cubic yards ;
 272 superficial feet 1½ bricks thick ;
 4352 stock bricks, 4 courses 1 foot high.

Bricks absorb about $\frac{1}{16}$ th of their weight of water.

A rod of brick-work requires about 3 cubic yards of mortar, or 1½ cubic yards of chalk lime and 3 loads of sand, or 1 cubic yard of stone lime and 3½ loads of sand, or 36 bushels of cement and an equal quantity of sand.

A load of mortar or of sand is 1 cubic yard.

A bag of cement is 3 bushels.

A sack of cement is 5 bushels.

A load of mortar requires about 9 bushels of lime and 1 cubic yard or-load of sand.

One load of bricks, 500 bricks.

330 stock bricks weigh 1 ton.

1000 bricks loosely stacked occupy about 72 cubic feet (14 bricks per cubic foot).

1000 bricks closely stacked occupy about 56 cubic feet (18 bricks per cubic foot).

Mortar is composed of 1 part of lime to 3 or 3½ parts of sharp sand.

Concrete is composed of 1 part of lime, 4 parts of gravel, and 2 parts of sand.

Cement is composed of 1 part of Portland cement to 3 parts of sand. Or cement alone may be used.

TABLE 32.—TONNAGE OF SHIPS (ENGLISH).

1 ton, displacement of a ship	35 cubic feet;
1 ton, freight by measurement	40 „
1 ton, registered internal capacity of a ship	100 „
1 ton, shipbuilders' old measurement	94 „

Wire-Gauges.

The oldest and best-known Birmingham Wire-Gauge is that of which the numbers were carefully measured by Mr. Holtzapffel, and published by him in 1847. He gives 40 measurements ranging from .454 inch to .004 inch, as recorded in Table 33. It was accepted by the Standards De-

ment of the Board of Trade. Although there are only 40 marks in the table, there were 60 different sizes of wire made, for which intermediate sizes were added to the gauge.

TABLE 33.—BIRMINGHAM WIRE-GAUGE.

(Stubs.)

Mark	Size.	Mark	Size.	Mark.	Size	Mark	Size.
No	Inch.	No	Inch.	No	Inch.	No	Inch.
1/0	·454	7	·180	17	·058	27	·016
3/0	·425	8	·165	18	·049	28	·014
2/0	·380	9	·148	19	·042	29	·013
0	·340	10	·134	20	·035	30	·012
1	·300	11	·120	21	·032	31	·010
2	·284	12	·109	22	·028	32	·008
3	·259	13	·095	23	·025	33	·008
4	·238	14	·083	24	·022	34	·007
5	·220	15	·072	25	·020	35	·006
6	·203	16	·065	26	·018	36	·004

The wire gauge that has been in common use by the sheet-rollers of South Staffordshire, ranges from $\frac{5}{16}$ inch to $\frac{1}{80}$ inch in thickness, according to the following Table —

TABLE 34.—BIRMINGHAM WIRE-GAUGE.

For Iron Sheets chiefly.

No.	Size.	No.	Size.	No.	Size.	No.	Size.
	Inch.		Inch.		Inch.		Inch.
1	·3125 ($\frac{1}{16}$)	9	·15625	17	·05625	25	·02344
2	·28125	10	·140625	18	·05 ($\frac{1}{20}$)	26	·021875
3	·25 ($\frac{1}{4}$)	11	·125 ($\frac{1}{8}$)	19	·04375	27	·020312
4	·234375	12	·1125	20	·0375	28	·01875
5	·21875	13	·10 ($\frac{1}{10}$)	21	·034375	29	·01719
6	·203125	14	·0875	22	·03125 ($\frac{1}{32}$)	30	·015625
7	·1875 ($\frac{3}{16}$)	15	·075	23	·028125	31	·01406
8	·171875	16	·0625 ($\frac{1}{16}$)	24	·025 ($\frac{1}{40}$)	32	·0125 ($\frac{1}{80}$)

Sir Joseph Whitworth, in 1857 promulgated his Standard Wire-Gauge, ranging from half an inch to one-thousandth of an inch, and comprising 62 measurements, given in Table 35. The sizes are designated or marked by their respective values. The Whitworth gauge has been in general use.

TABLE 35.—WHITWORTH WIRE-GAUGE, 1857.

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
1	.001	17	.017	55	.055	200	.200
2	.002	18	.018	60	.060	220	.220
3	.003	19	.019	65	.065	240	.240
4	.004	20	.020	70	.070	260	.260
5	.005	22	.022	75	.075	280	.280
6	.006	24	.024	80	.080	300	.300
7	.007	26	.026	85	.085	325	.325
8	.008	28	.028	90	.090	350	.350
9	.009	30	.030	95	.095	375	.375
10	.010	32	.032	100	.100	400	.400
11	.011	34	.034	110	.110	425	.425
12	.012	36	.036	120	.120	450	.450
13	.013	38	.038	135	.135	475	.475
14	.014	40	.040	150	.150	500	.500
15	.015	45	.045	165	.165		
16	.016	50	.050	180	.180		

TABLE 36.—IMPERIAL STANDARD WIRE-GAUGE.

Descrip- tive Number.	Equivalents in Parts of an Inch.	Metric Equivalents.	Sectional Area of Wire.	
No.	Inch.	Millimetres	Square Inch.	Square Millimetres.
7/0	.500	12.700	.1963	126.67
6/0	.464	11.785	.1691	109.09
5/0	.432	10.973	.1466	94.56
4/0	.400	10.160	.1257	81.07
3/0	.372	9.449	.1087	70.12
2/0	.348	8.839	.0951	61.36
0	.324	8.229	.0821	53.19
1	.300	7.620	.0707	45.60
2	.276	7.010	.0598	38.58
3	.252	6.401	.0499	32.18
4	.232	5.893	.0423	27.27
5	.212	5.385	.0373	22.77
6	.192	4.877	.0289	18.68
7	.176	4.470	.0243	15.70
8	.160	4.064	.0201	12.97
9	.144	3.658	.0163	10.75

TABLE 36.—IMPERIAL STANDARD WIRE-GAUGE (*continued*)

Descriptive Number	Equivalents in Parts of an Inch.	Metric Equivalents.	Sectional Area of Wire.	
No.	Inch.	Millimetres.	Square Inch.	Square Millimetres.
10	128	3.251	.0129	8.30
11	116	2.946	.0106	6.82
12	104	2.642	.00849	5.48
13	92	2.337	.00665	4.29
14	80	2.032	.00503	3.24
15	72	1.829	.00407	2.63
16	64	1.626	.00322	2.07
17	56	1.423	.00246	1.59
18	48	1.219	.00181	1.17
19	40	1.016	.00126	.811
20	36	.914	.00102	.657
21	32	.813	.00084	.519
22	28	.711	.000616	.397
23	24	.610	.000452	.294
24	22	.559	.000380	.244
25	20	.508	.000314	.203
26	18	.457	.000254	.164
27	16	.406	.000211	.136
28	14	.355	.000173	.111
29	13	.345	.000145	.093
30	12	.315	.000121	.077
31	11	.294	.000106	.068
32	10	.274	.0000916	.059
33	9	.254	.0000785	.0507
34	0092	.2337	.0000665	.0429
35	0084	.2134	.0000544	.0357
36	0076	.1930	.0000474	.0294
37	0068	.1727	.0000363	.0234
38	0060	.1524	.0000283	.0182
39	0052	.1321	.0000212	.0139
40	0048	.1219	.0000181	.0117
41	0044	.1118	.0000152	.0096
42	0040	.1016	.0000126	.0082
43	0036	.0914	.0000102	.0066
44	0032	.0813	.0000804	.0051
45	0028	.0711	.0000616	.0039
46	0024	.0610	.0000452	.0029
47	0020	.0508	.0000314	.0020
48	0016	.0406	.0000211	.0013
49	0012	.0305	.0000113	.0007
50	0010	.0254	.00000785	.0005

TABLE 37.—WARRINGTON WIRE GAUGE.
(Rylands Brothers.)
(Rarely used now.)

Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.
7/0	$\frac{1}{2}$	4	.229	13	.090
6/0	$\frac{1}{8}$	5	.209	14	.079
5/0	$\frac{7}{32}$	6	.191	15	.069
4/0	$\frac{13}{64}$	7	.174	16	.0625 or $\frac{1}{16}$
3/0	$\frac{3}{8}$	8	.159	17	.053
2/0	$\frac{11}{32}$	9	.146	18	.047
0	.326	10	.135	19	.041
1	.300	10 $\frac{1}{2}$	.125 or $\frac{1}{8}$	20	.036
2	.274	11	.117	21	.0315 or $\frac{1}{32}$
3	.250 or $\frac{1}{4}$	12	.100 or $\frac{1}{10}$	22	.028

TABLE 38.—HOLTZAPFFEL'S LANCASHIRE GAUGE.
(For Round Steel Wire and Piano Wire.)

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
80	.013	57	.042	34	.109	11	.189	M	.295
79	.014	56	.044	33	.111	10	.190	N	.302
78	.015	55	.050	32	.115	9	.191	O	.316
77	.016	54	.055	31	.118	8	.192	P	.328
76	.018	53	.058	30	.125	7	.195	Q	.332
75	.019	52	.059	29	.134	6	.198	R	.339
74	.022	51	.064	28	.138	5	.201	S	.348
73	.023	50	.067	27	.141	4	.204	T	.358
72	.024	49	.070	26	.143	3	.209	U	.368
71	.026	48	.073	25	.146	2	.210	V	.377
70	.027	47	.076	24	.148	1	.227	W	.386
69	.029	46	.078	23	.150	A	.234	X	.397
68	.030	45	.080	22	.152	B	.238	Y	.404
67	.031	44	.084	21	.157	C	.242	Z	.413
66	.032	43	.086	20	.160	D	.246	A1	.420
65	.033	42	.091	19	.164	E	.250	B1	.431
64	.034	41	.095	18	.167	F	.257	C1	.443
63	.035	40	.096	17	.169	G	.261	D1	.452
62	.036	39	.098	16	.174	H	.266	E1	.462
61	.038	38	.100	15	.175	I	.272	F1	.473
60	.039	37	.102	14	.177	K $\frac{1}{2}$	.277	G1	.484
59	.040	36	.105	13	.180	K	.281	H1	.494
58	.041	35	.107	12	.185	L	.290		

The Imperial Standard Wire-Gauge was legally established March 1, 1884. It is given in Table 36.

The Warrington Wire-Gauge, formerly practised by Rylance Brothers, is given in Table 37. It is rarely used now.

The Lancashire Gauge, Table 38, arranged by Holtzapfel, is employed for the manufacture of bright steel wire in Lancashire, and steel pin-wire used in clocks and watches. The larger sizes, distinguished by letters, form the *Letter Gauge*.

There are also the Needle-gauge, for needle-wire, and the Music Wire-gauge, for the strings of pianofortes.

TABLE 39.—ADMIRALTY KNOTS AND STATUTE MILES.

Knots.	Miles.	Knots.	Miles.	Knots.	Miles.	Knots.	Miles.
10	11.152	5.50	6.3333	12.25	14.1061	18.75	21.590
20	22.303	7.75	6.6212	12.50	14.3939	19.00	21.878
30	33.455	6.00	6.9091	12.75	14.6818	19.25	22.166
40	44.606	6.25	7.1970	13.00	14.9697	19.50	22.454
50	55.758	6.50	7.4848	13.25	15.2576	19.75	22.742
60	66.909	6.75	7.7727	13.50	15.5455	20.00	23.030
70	78.061	7.00	8.0606	13.75	15.8333	20.50	23.606
80	89.212	7.25	8.3485	14.00	16.1212	21.00	24.181
90	100.363	7.50	8.6364	14.25	16.4091	21.50	24.757
1.00	111.515	7.75	8.9242	14.50	16.6970	22.00	25.333
1.25	143.94	8.00	9.2121	14.75	16.9848	22.50	25.909
1.50	172.73	8.25	9.5000	15.00	17.2727	23.00	26.484
1.75	201.52	8.50	9.7879	15.25	17.5606	23.50	27.060
2.00	230.30	8.75	10.0758	15.50	17.8485	24.00	27.636
2.25	259.09	9.00	10.3636	15.75	18.1364	24.50	28.212
2.50	287.88	9.25	10.6515	16.00	18.4242	25.00	28.787
2.75	316.67	9.50	10.9394	16.25	18.7121	25.50	29.363
3.00	345.46	9.75	11.2273	16.50	19.0000	26.00	29.939
3.25	374.24	10.00	11.5152	16.75	19.2879	26.50	30.515
3.50	403.03	10.25	11.8030	17.00	19.5758	27.00	31.090
3.75	431.82	10.50	12.0909	17.25	19.8636	27.50	31.666
4.00	460.61	10.75	12.3788	17.50	20.1515	28.00	32.242
4.25	489.39	11	12.6667	17.75	20.4394	28.50	32.818
4.50	518.18	11.25	12.9545	18.00	20.7273	29.00	33.394
4.75	546.97	11.50	13.2424	18.25	21.0152	29.50	33.969
5.00	575.76	11.75	12.5303	18.50	21.3030	30.00	34.545
5.25	604.55	12.00	13.8182				

TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS.

Advancing by Eighths.

Eighths.	Fractions.	Decimals of an Inch.	Eighths.	Fractions.	Decimals of an Inch.
1	$\frac{1}{8}$	·125	5	$\frac{5}{8}$	·625
2	$\frac{1}{4}$	·25	6	$\frac{3}{4}$	·75
3	$\frac{3}{8}$	·375	7	$\frac{7}{8}$	·875
4	$\frac{1}{2}$	·5	8	1	1·0

Advancing by Twelfths.

Twelfths.	Fractions.	Decimals of an Inch.	Twelfths.	Fractions.	Decimals of an Inch.
1	$\frac{1}{12}$	·0833̄	7	$\frac{7}{12}$	·5833̄
2	$\frac{1}{6}$	·1666̄	8	$\frac{2}{3}$	·6666̄
3	$\frac{1}{4}$	·25	9	$\frac{3}{4}$	·75
4	$\frac{1}{3}$	·3333̄	10	$\frac{5}{6}$	·8333̄
5	$\frac{5}{12}$	·4166̄	11	$\frac{11}{12}$	·9166̄
6	$\frac{1}{2}$	·5	12	1	1·0

Advancing by Sixteenths.

Sixteenths.	Fractions.	Decimals of an Inch.	Sixteenths.	Fractions.	Decimals of an Inch.
1	$\frac{1}{16}$	·0625	9	$\frac{9}{16}$	·5625
2	$\frac{1}{8}$	·125	10	$\frac{5}{8}$	·625
3	$\frac{3}{16}$	·1875	11	$\frac{11}{16}$	·6875
4	$\frac{1}{4}$	·25	12	$\frac{3}{4}$	·75
5	$\frac{5}{16}$	·3125	13	$\frac{13}{16}$	·8125
6	$\frac{3}{8}$	·375	14	$\frac{7}{8}$	·875
7	$\frac{7}{16}$	·4375	15	$\frac{15}{16}$	·9375
8	$\frac{1}{2}$	·5	16	1	1·0

TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS (*continued*).*Advancing by Thirty-seconds.*

Thirty-seconds.	Fractions	Decimals of an Inch.	Thirty-seconds.	Fractions.	Decimals of an Inch.
1	$\frac{1}{32}$	·03125	17	$\frac{17}{32}$	·53125
2	$\frac{1}{16}$	·0625	18	$\frac{9}{16}$	·5625
3	$\frac{3}{32}$	·09375	19	$\frac{19}{32}$	·59375
4	$\frac{1}{8}$	·125	20	$\frac{5}{8}$	·625
5	$\frac{5}{32}$	·15625	21	$\frac{21}{32}$	·65625
6	$\frac{3}{16}$	·1875	22	$\frac{11}{16}$	·6875
7	$\frac{7}{32}$	·21875	23	$\frac{23}{32}$	·71875
8	$\frac{1}{4}$	·25	24	$\frac{3}{4}$	·75
9	$\frac{9}{32}$	·28125	25	$\frac{25}{32}$	·78125
10	$\frac{5}{16}$	·3125	26	$\frac{13}{16}$	·8125
11	$\frac{11}{32}$	·34375	27	$\frac{27}{32}$	·84375
12	$\frac{3}{8}$	·375	28	$\frac{7}{8}$	·875
13	$\frac{13}{32}$	·40625	29	$\frac{29}{32}$	·90625
14	$\frac{7}{16}$	·4375	30	$\frac{15}{16}$	·9375
15	$\frac{15}{32}$	·46875	31	$\frac{31}{32}$	·96875
16	$\frac{1}{2}$	·5	32	1	1·0

Advancing by odd Sixty-fourths.

Sixty-fourths.	Decimals of an Inch.	Sixty-fourths.	Decimals of an Inch.
1	·015625	35	·546875
3	·031250	37	·578125
5	·078125	39	·609375
7	·109375	41	·640625
9	·140625	43	·671875
11	·171875	45	·703125
13	·203125	47	·734375
15	·234375	49	·765625
17	·265625	51	·796875
19	·296875	53	·828125
21	·328125	55	·859375
23	·359375	57	·890625
25	·390625	59	·921875
27	·421875	61	·953125
29	·453125	63	·984375
31	·484375	64	1·0
33	·515625		

TABLE 41.—LINEAL INCHES IN DECIMAL FRACTIONS OF A LINEAL FOOT.

Lineal Inches	Lineal Foot	Lineal Inches	Lineal Foot.	Lineal Inches.	Lineal Foot.
$\frac{1}{8}$	.001302083	$1\frac{1}{8}$	.15625	$6\frac{1}{2}$	.54.6
$\frac{1}{4}$	.00260416	2	.1666	6\frac{3}{4}	.5625
$\frac{1}{16}$	.0052083	$2\frac{1}{8}$	.177083	7	.5833
$\frac{1}{8}$	.010416	$2\frac{1}{4}$	.1875	$7\frac{1}{4}$	.60416
$\frac{3}{16}$	.015625	$2\frac{3}{8}$	.197916	$7\frac{1}{2}$	.625
$\frac{1}{4}$	.02083	$2\frac{1}{2}$	.2083	$7\frac{3}{4}$	.64583
$\frac{5}{16}$	.0260416	$2\frac{5}{8}$	.21875	8	.6666
$\frac{3}{8}$	.03125	$2\frac{3}{4}$	.22916	$8\frac{1}{4}$	.6875
$\frac{7}{16}$	.0364583	$2\frac{7}{8}$	.239583	$8\frac{1}{2}$	.7083
$\frac{1}{2}$	.0416	3	.25	$8\frac{3}{4}$	.72916
$\frac{9}{16}$	.046875	$3\frac{1}{4}$	.27083	9	.75
$\frac{5}{8}$	.052083	$3\frac{1}{2}$	.2916	$9\frac{1}{4}$	.77083
$\frac{11}{16}$	.0572916	$3\frac{3}{4}$	.3125	$9\frac{1}{2}$	.7916
$\frac{3}{4}$	.0625	4	.3333	$9\frac{3}{4}$	.8125
$\frac{13}{16}$	.0677083	$4\frac{1}{4}$	.35416	10	.8333
$\frac{7}{8}$	.072916	$4\frac{1}{2}$	.375	$10\frac{1}{4}$	.85416
$\frac{15}{16}$	.078125	$4\frac{3}{4}$	.39583	$10\frac{1}{2}$	.875
1	.0833	5	.4166	$10\frac{3}{4}$	.89583
$1\frac{1}{8}$	.09577	$5\frac{1}{4}$	.4375	11	.9166
$1\frac{1}{4}$	.10416	$5\frac{1}{2}$	.4583	$11\frac{1}{4}$	.9375
$1\frac{3}{8}$	.114583	$5\frac{3}{4}$	.47916	$11\frac{1}{2}$	.9583
$1\frac{1}{2}$	.125	6	.5	$11\frac{3}{4}$	.97916
$1\frac{5}{8}$	.135416	$6\frac{1}{4}$	.52083	12	1.0000
$1\frac{3}{4}$	.14583				

TABLE 42. SQUARE INCHES IN DECIMAL FRACTIONS OF A SQUARE FOOT.

Square Inches	Square Feet	Square Inches	Square Feet	Square Inches	Square Feet	Square Inches	Square Feet
10	0006944	24	16966	65	47738	105	72916
15	0010416	25	17361	66	48333	106	73611
20	001388	26	18755	67	49027	107	74305
25	0017361	27	18750	68	47222	108	75000
30	002083	28	19441	69	47916	109	75694
35	0024305	29	20138	70	48611	110	76388
40	0027777	30	20833	71	49305	111	77083
45	0031249	31	21527	72	50000	112	77777
50	003472	32	22222	73	50694	113	78472
55	0038194	33	22916	74	51388	114	79166
60	0041665	34	23611	75	52083	115	79861
65	0045138	35	24305	76	52777	116	80555
70	004861	36	25000	77	53472	117	81249
75	0052083	37	25694	78	54166	118	81944
80	0055555	38	26388	79	54861	119	82638
85	0059027	39	27083	80	55555	120	83333
90	0062500	40	27777	81	56250	121	84027
95	0065972	41	28472	82	56944	122	84722
1	0069444	42	29166	83	57638	123	85416
2	01388	43	29861	84	58333	124	86111
3	02083	44	30555	85	59027	125	86805
4	02777	45	31249	86	59722	126	87500
5	03472	46	31944	87	60416	127	88194
6	04166	47	32638	88	61111	128	88888
7	04861	48	33333	89	61805	129	89583
8	05555	49	34027	90	62500	130	90277
9	06250	50	34722	91	63194	131	90972
10	06944	51	35416	92	63888	132	91666
11	07638	52	36111	93	64583	133	92361
12	08333	53	36805	94	65277	134	93055
13	09027	54	37500	95	65972	135	93750
14	09722	55	38194	96	66666	136	94444
15	10416	56	38888	97	67361	137	95138
16	11111	57	39583	98	68055	138	95833
17	11805	58	40277	99	68750	139	96527
18	12500	59	40972	100	69444	140	97222
19	13194	60	41666	101	70138	141	97916
20	13888	61	42361	102	70833	142	98611
21	14583	62	43055	103	71527	143	99305
22	15277	63	43750	104	72222	144	100000
23	15972	64	44444				

TABLE 43.—DECIMAL FRACTIONS OF A SQUARE FOOT IN SQUARE INCHES.

Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.
·01	1·44	·26	37·4	·51	73·4	·76	109·4
·02	2·88	·27	38·9	·52	74·9	·77	110·9
·03	4·32	·28	40·3	·53	76·3	·78	112·3
·04	5·76	·29	41·8	·54	77·8	·79	113·8
·05	7·20	·30	43·2	·55	79·2	·80	115·2
·06	8·64	·31	44·6	·56	80·6	·81	116·6
·07	10·1	·32	46·1	·57	82·1	·82	118·1
·08	11·5	·33	47·5	·58	83·5	·83	119·5
·09	13·0	·34	49·0	·59	85·0	·84	121·0
·10	14·4	·35	50·4	·60	86·4	·85	122·4
·11	15·8	·36	51·8	·61	87·8	·86	123·8
·12	17·3	·37	53·3	·62	89·3	·87	125·3
·13	18·7	·38	54·7	·63	90·7	·88	126·7
·14	20·2	·39	56·2	·64	92·2	·89	128·2
·15	21·6	·40	57·6	·65	93·6	·90	129·6
·16	23·0	·41	58·0	·66	95·0	·91	131·0
·17	24·5	·42	60·5	·67	96·5	·92	132·5
·18	25·9	·43	61·9	·68	97·9	·93	133·9
·19	27·4	·44	63·4	·69	99·4	·94	135·4
·20	28·8	·45	64·8	·70	100·8	·95	136·8
·21	30·2	·46	66·2	·71	102·2	·96	138·2
·22	31·7	·47	67·7	·72	103·7	·97	139·7
·23	33·1	·48	69·1	·73	105·1	·98	141·1
·24	34·6	·49	70·6	·74	106·6	·99	142·6
·25	36·0	·50	72·0	·75	108·0	1·00	144·0

TABLE 44.—CORRELATIVE RATES (ENGLISH).

100 lbs. per cubic foot	. . .	<div> <div>·926 ounce per cubic inch.</div> <div>24·107 cwt. per cubic yard.</div> <div>1·2053 tons per cubic yard.</div> </div>
1 cwt. per cubic yard	. . .	4·148 lbs. per cubic foot.
1 ton per cubic yard	. . .	82·963 lbs. per cubic foot.
1 grain per gallon (1 in 70,000 parts, by weight, of water)	. . .	<div>6·2321 grains per cubic foot.</div> <div>163·36 grains per cubic yard.</div> <div>220·09 grains per cubic meter.</div>
1 lb. per lineal yard	. . .	·7857 ton per mile.

TABLE 44. — CORRELATIVE RATES (ENGLISH) — (*continued*)

	144 lbs. per square foot.
	1296 lbs. per square yard.
	6786 ton per square yard.
1 lb. per square inch . . .	2.0353 inches of mercury at 32° F.
	2.0416 inches of mercury at 62° F.
	2.309 feet of water at 62° F.
	27.71 inches of water at 62° F.
	2116.4 lbs. per square foot.
1 atmosphere (14.7 lbs. per square inch) . . .	8.503 tons per square yard.
	33.947 feet of water at 62° F.
	10.347 metres of water at 62° F.
	30 inches of mercury at 62° F.
1 lb. per square foot	{ .00694 lb. per square inch.
	{ .1111 ounce per square inch.
	{ .0804 cwt. per square yard.
1 inch of water at 62° F.	{ .5773 ounce per square inch.
	{ 0.361 lb. per square inch.
	{ 5.20 lbs. per square foot.
	{ .0736 inch of mercury at 62° F.
1 foot of water at 62° F.	{ .433 lb. per square inch.
	{ 62.355 lbs. per square foot.
	{ 88.4 inch of mercury at 62° F.
1 inch of mercury at 62° F.	{ 49 lb. per square inch.
	{ 70.56 lbs. per square foot.
	{ 1.165 feet of water at 62° F.
	{ 14 inches of water at 62° F.
1 cubic foot per second	{ 2.222 cubic yards per minute.
	{ 133.333 cubic yards per hour.
1 cubic foot per minute	2.222 cubic yards per hour.
.45 cubic foot per minute	1 cubic yard per hour.
1 cubic inch per second	{ 2.083 cubic feet per hour.
	{ 12.084 gallons per hour.
1 mile per hour . . .	{ 1.467 feet per second.
	{ 88 feet per minute.
1 foot per second .	.682 mile per hour.
1 foot per minute	{ .01136 mile per hour.
	{ .20 inch per second.
1 inch per second	5 feet per minute.

TABLE 45.—WATER.

	{ 277·274 cubic inches. { 1604 cubic foot.
1 Imperial gallon	10 pounds of water at 62° F. 70,000 grains of water at 62° F. 1·20 U S gallons. 4·544 litres.
1 U. S. gallon	{ 231 cubic inches. { 1337 cubic foot. 8·333 pounds of water at 62° F. ·8333 imperial gallon (qths). 3·786 litres.
1 cubic inch of water at 62° F.	·03608 pound. ·5773 ounce. 252·6 grains. ·003607 imperial gallon. ·004326 U.S. gallon. ·01698 litre.
1 cubic foot of water at 62° F.	62·355 pounds. 997·88 ounces (about 1000). ·557 cwt. ·0278 ton.
1 cylindrical inch of water at 62° F.	6·2355 imperial gallons. 49·884 imperial pints (about 50). 7·4805 U.S. gallons. 28·315 litres. ·02832 cubic metre.
1 cylindrical foot of water at 62° F.	·02833 pound. ·4533 ounce. 7854 cubic inch. 48·973 pounds (about 50). 783·57 ounces. ·437 cwt.
1 cubic yard of water	·0219 ton. 4·8973 imperial gallons. 5·8758 U.S. gallons. 22·2380 litres. ·02224 cubic metre.
1 litre of water	1684·8 pounds. 15·043 cwt., or 15 cwt. 4·8 pounds. 7645 cubic metre. 2·2046 pounds at 62° F. ·2201 imperial gallon. 1·761 imperial pint. ·2641 U.S. gallon. 61·025 cubic inches. ·0053 cubic foot.

TABLE 45.—WATER (*continued*).

	1 tonne, or 1000 kilogrammes at 39.1° F. or 4° C.
	2204.62 pounds at 39.1° F. or 4° C.
	2208.7 pounds at 62.4 pounds per cubic foot.
	1 ton of 2240 pounds, nearly.
1 cubic metre of water.	1 tun of 4 hogsheads or 2100 pounds, nearly.
	220.1 imperial gallons.
	264.2 U.S. gallons.
	1.308 cubic yards.
	35.3156 cubic feet.
	1000 litres.

The weight of fresh water is commonly assumed, in ordinary calculations, to be 62.4 pounds per cubic foot, which is the weight at 52.8° F. It is frequently taken as 62½ pounds or 1000 ounces per cubic foot.

The volumes of given weights of water, at the rate of 62.4 pounds per cubic foot, are as follows:—

1 ton	35.90 cubic feet (about 36).
1 cwt.	1.795 "
1 pound	.016 "
1 ounce	1.731 "
1 tonne, at 39.1° F. or 4° C.	35.3156 cubic feet.
1 kilogramme	{ .0353 "
	{ 61.025 cubic inches.
1 tonne, at 52.8° F. (62.4 pounds per cubic foot)	} 35.330 cubic feet.

A pipe 1 yard in length holds about as many pounds of water of ordinary temperatures as the square of its diameter in inches (about two per cent. more).

A column of water at 62° F. 1 foot high, is equivalent to a pressure of 433 pound, or 6928 ounces per square inch of base, or to 62.333 pounds per square foot.

A column of water 1 inch high is equivalent to a pressure of .5773 ounce, or .03608 pound per square inch; or to 5.198 pounds per square foot.

A column of water 100 feet high is equivalent to 43½ pounds per square inch, or 2.786 tons per square foot.

A column of water 1 mile deep, weighing 62.4 pounds per cubic foot, is equivalent to a pressure of about 1 ton per square inch.

1 pound per square inch is equivalent to a column of water at 62° F. 2·31 feet or 27·72 inches high.

Sea Water.

1 cubic foot at 62° F.	64 pounds.
1 cubic yard	15½ cwt. nearly (8 pounds less).
1 cubic metre	1 ton fully (20 pounds more).
1 ton	35 cubic feet.
Ratio of weight of fresh water to that of sea water	} 39 to 40, or 1 to 1·028.

Ice and Snow.

1 cubic foot of ice at 32° F.	57·50 pounds.
1 pound of ice " "	{ ·0174 cubic foot, or 30·067 cubic inches.
Specific density of ice, ·922 ; that of water at 62° F. being 1.	
1 cubic foot of fresh snow, according to humidity of atmosphere : 5 pounds to 12 pounds (Trautwine).	
1 cubic foot of snow moistened and com- pacted by rain	{ 15 pounds to 50 pounds (Trautwine).

TABLE 46.—AIR.

	·080728 pound at 32° F.
1 cubic foot, at 14·7 lbs. per square inch, or 1 atmosphere	1·29 ounce " "
	565·1 grains " "
	·076097 pound at 62° F.
	1·217 ounce " "
	532·7 grains " "
1 litre, under one atmosphere	{ 1·293 grammes at 32° F.
	{ 19·955 grains " "
1 pound of air at 62° F.	13·141 cubic feet.
The weights of equal volumes of mercury, water and air at 62° F. under 1 atmosphere, are as 11140·56, 819·4 and 1.	
	{ 14·7 lbs. per square inch.
	{ 2116·4 lbs. per square foot.
	{ 1·0335 kilogrammes per square centimetre.
1 atmosphere of pressure	{ 29·922 inches of mercury at 32° F.
	{ 76 centimetres of mercury at 32° F.
	{ 30 inches of mercury at 62° F.
	{ 33·947 feet of water at 62° F.
	{ 10·347 metres of water at 62° F.

TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS (*continued*).*Advancing by Thirty-seconds.*

Thirty seconds.	Fractions.	Decimals of an inch.	Thirty seconds.	Fractions.	Decimals of an inch.
1	$\frac{1}{32}$	03125	17	$\frac{17}{32}$	53125
2	$\frac{1}{16}$	0625	18	$\frac{9}{16}$	5625
3	$\frac{3}{32}$	09375	19	$\frac{19}{32}$	59375
4	$\frac{1}{8}$	125	20	$\frac{5}{8}$	625
5	$\frac{5}{32}$	15625	21	$\frac{21}{32}$	65625
6	$\frac{3}{16}$	1875	22	$\frac{11}{16}$	6875
7	$\frac{7}{32}$	21875	23	$\frac{23}{32}$	71875
8	$\frac{1}{4}$	25	24	$\frac{3}{4}$	75
9	$\frac{9}{32}$	28125	25	$\frac{25}{32}$	78125
10	$\frac{5}{16}$	3125	26	$\frac{13}{16}$	8125
11	$\frac{11}{32}$	34375	27	$\frac{27}{32}$	84375
12	$\frac{3}{8}$	375	28	$\frac{7}{8}$	875
13	$\frac{13}{32}$	40625	29	$\frac{29}{32}$	90625
14	$\frac{7}{16}$	4375	30	$\frac{15}{16}$	9375
15	$\frac{15}{32}$	46875	31	$\frac{31}{32}$	96875
16	$\frac{1}{2}$	5	32	1	1-0

Advancing by odd Sixty-fourths.

Sixty-fourths.	Decimals of an inch.	Sixty-fourths.	Decimals of an inch.
1	015625	35	546875
3	031250	37	578125
5	078125	39	609375
7	109375	41	640625
9	140625	43	671875
11	171875	45	703125
13	203125	47	734375
15	234375	49	765625
17	265625	51	796875
19	296875	53	828125
21	328125	55	859375
23	359375	57	890625
25	390625	59	921875
27	421875	61	953125
29	453125	63	984375
31	484375	64	1-0
33	515625		

TABLE 41.—LINEAL INCHES IN DECIMAL FRACTIONS OF A LINEAL FOOT

Lineal Inches.	Lineal Foot	Lineal Inches	Lineal Foot.	Lineal Inches	Lineal Foot.
$\frac{1}{64}$	.001302083	$1\frac{1}{2}$	.15625	$6\frac{1}{2}$	.5416
$\frac{1}{32}$	.00260416	2	.1666	$6\frac{3}{4}$	.5625
$\frac{1}{16}$	.0052083	$2\frac{1}{8}$	.177083	7	.5833
$\frac{1}{8}$	.010416	$2\frac{1}{4}$	.1875	$7\frac{1}{4}$	.60416
$\frac{3}{16}$	.015625	$2\frac{3}{8}$	.197916	$7\frac{1}{2}$	.625
$\frac{1}{4}$	.02083	$2\frac{1}{2}$	.2083	$7\frac{3}{4}$	.64583
$\frac{5}{16}$	.0260416	$2\frac{5}{8}$	.21875	8	.6666
$\frac{3}{8}$	.03125	$2\frac{3}{4}$	.22916	$8\frac{1}{4}$	.6875
$\frac{7}{16}$	.0364583	$2\frac{7}{8}$	.239583	$8\frac{1}{2}$	.7083
$\frac{1}{2}$	.0416	3	.25	$8\frac{3}{4}$	.72916
$\frac{9}{16}$	.046875	$3\frac{1}{4}$	.27083	9	.75
$\frac{5}{8}$	.052083	$3\frac{1}{2}$	.2916	$9\frac{1}{4}$	.77083
$\frac{11}{16}$	.0572916	$3\frac{3}{4}$	.3125	$9\frac{1}{2}$	.7916
$\frac{3}{4}$	.0625	4	.3333	$9\frac{3}{4}$	.8125
$\frac{13}{16}$	.0677083	$4\frac{1}{4}$	.35416	10	.8333
$\frac{7}{8}$	.072916	$4\frac{1}{2}$	.375	$10\frac{1}{4}$	.85416
$\frac{15}{16}$	.078125	$4\frac{3}{4}$	.39583	$10\frac{1}{2}$	.875
1	.0833	5	.4166	$10\frac{3}{4}$	.89583
$1\frac{1}{16}$	.09875	$5\frac{1}{4}$	.4375	11	.9166
$1\frac{1}{8}$	.10416	$5\frac{1}{2}$	.4583	$11\frac{1}{4}$	.9375
$1\frac{1}{4}$	.114583	$5\frac{3}{4}$	.47916	$11\frac{1}{2}$	.9583
$1\frac{1}{2}$	.125	6	.5	$11\frac{3}{4}$	.97916
$1\frac{3}{8}$	.135416	$6\frac{1}{4}$	.52083	12	1.0000
$1\frac{1}{2}$	.14583				

TABLE 46. AIR (*continued*).

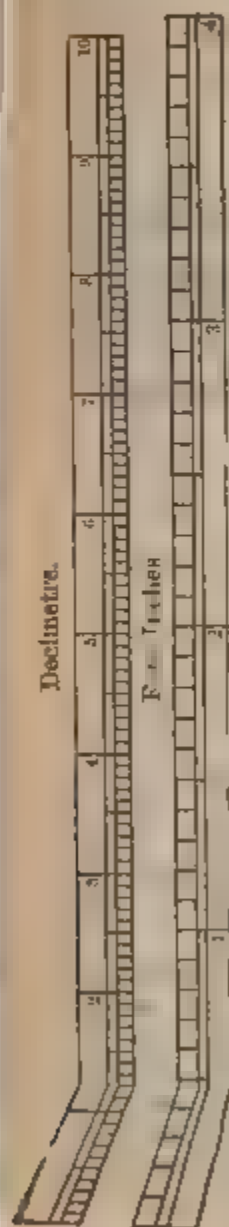
	2.035 inches of mercury at 32° F.
	51.7 millimetres
1 lb. per square inch .	2.04 inches of mercury at 62° F.
	2.31 feet of water at 62° F.
	27.72 inches " "
1 ounce per square inch .	1.732 inches " "
	1.925 inch " "
1 lb. per square foot .	0.1417 inch of mercury at 62° F.

French Metric Weights and Measures.

The metre, equal to 39.37043 inches, and the kilogramme, equal to 2.20462 pounds, are the only standards of weight and measure in France. The kilogramme is defined as the weight of a cubic decimetre of distilled water at its maximum density, at 4° C. or 39.1° F. It is legally taken to be 2.20462125 pounds. The gramme, of which there are one thousand in the kilogramme, is the unit of weight. It is the weight of one cubic centimetre of water under the conditions above defined.

The metric unit of capacity is the litre, defined as equal to a cubic decimetre. It is equal to 0.22009 gallon.

The French metric system has been compulsorily adopted by France and Belgium in 1801, Holland in 1819; Greece in 1836, Italy and Spain, in 1859; Portugal, in 1860-68; the German Empire, in 1872, Colombia, Venezuela, in 1872. The system is established in France and her Colonies, Belgium, Holland and her Colonies, Germany, Sweden, Norway, Austro-Hungary, Italy, Spain, Portugal, Turkey, Roumania, Greece, Brazil, Colombia, Uruguay, Ecuador, Peru, Chile, the Argentine Republic. It has been made legally optional in Great Britain and Ireland, the United States of North America and Canada. It is admitted in principle, or partially for customs, in British India, Russia, and Venezuela. Switzerland, in 1856, legalised the foot and three decimetres as the unit of length, with a decimal scale, with a unit of weight, the pound of 500 grammes, or half a kilogramme, with two distinct scales of multiples and parts, one decimal, the other on the old system. Denmark adopted the metric system so far as the pound of 500 grammes.



FIGS. 17-18. French and English Measures compared.

TABLE 47.—FRENCH MEASURES OF LENGTH.

		Metres.	English Equivalents.
1 millimetre	=	·001	= ·03937 in., or $\frac{1}{25}$ in. nearly.
10 millimetres	= 1 centimetre	= ·01	= ·3937 inch.
10 centimetres	= 1 decimetre	= ·1	= 3·93704 in., or 4 ins. nearly.
10 decimetres	} = 1 METRE	= 1	{ 39·3704 ins. 3·2809 feet.
100 centimetres			
1000 millimetres			
10 metres	= 1 decametre	= 10	= 32·8087 feet.
10 decametres	= 1 hectometre	= 100	{ 328·0869 feet. 109·3623 yds.
10 hectometres	= 1 KILOMETRE	= 1000	{ 3280·869 feet.. 1093·623 yds. ·62138mle.
10 kilometres	= 1 myriametre	= 10,000	= 6·21377 miles..

TABLE 48.—FRENCH MEASURES OF SURFACE.

		Sq. Metres.	English Equivalents.
1 sq. millimetre		·000001	·00155 sq. in.
100 square millimetres	} 1 sq. centimetre .	·0001	·155 sq. in.
100 square centimetres.			
100 square decimetres.	} 1 sq. decimetre .	·01	15·5003 sq. ins.
10,000 square centimetres.			
100 square metres.	} 1 square metre or centiare . .	1	{ 10·7641 sq. ft. 1·1960 sq. yds.
100 square decametres.			
100 square metres.	} 1 sq. decametre, or are	100	{ 1076·41 sq. ft. 119·601 sq. yds.
100 square decametres.			
100 square hectometres.	} 1 sq. hectometre or hectare, or metrical acre .	10,000	{ 11,960·11 sq. yds. 2·4711 acres.
100 square kilometres.			
100 square kilometres.	} 1 sq. kilometre .	1,000,000	{ 1,196,014 sq. yds. ·38611 sq. mile.
100 square kilometres.			
100 square kilometres.	} 1 sq. myriametre .	100,000,000	= 38·611 sq. miles
100 square kilometres.			

Land is measured in terms of the centiare, the are, and the hectare.

Wood (France).

The large pieces of timber, cut from the trees, are of the following ordinary squared sizes.

	Metre.	Inches.
<i>Oak</i>	·10 to ·30	3·94 to 11·8
<i>Small stowage (Petit arrimage)</i>	·30 to ·40	11·8 to 15·7

TABLE 42.—SQUARE INCHES IN DECIMAL FRACTIONS OF A SQUARE FOOT.

Square Inches	Square Foot	Square Inches	Square Foot	Square Inches	Square Foot	Square Inches	Square Foot
10	0006944	24	16666	65	45138	105	72916
15	0010416	25	17361	66	45833	106	73611
20	001388	26	18056	67	46527	107	74305
25	0017361	27	18750	68	47222	108	75000
30	002083	28	19444	69	47916	109	75694
35	0024305	29	20138	70	48611	110	76388
40	002777	30	20833	71	49305	111	77083
45	0031249	31	21527	72	50000	112	77777
50	003472	32	22222	73	50694	113	78472
55	0038194	33	22916	74	51388	114	79166
60	004166	34	23611	75	52083	115	79861
65	0045138	35	24305	76	52777	116	80555
70	004861	36	25000	77	53472	117	81249
75	0052083	37	25694	78	54166	118	81944
80	0055555	38	26388	79	54861	119	82638
85	0059027	39	27083	80	55555	120	83333
90	0062500	40	27777	81	56250	121	84027
95	0065972	41	28472	82	56944	122	84722
1	006944	42	29166	83	57638	123	85416
2	01388	43	29861	84	58333	124	86111
3	02083	44	30555	85	59027	125	86805
4	02777	45	31249	86	59722	126	87500
5	03472	46	31944	87	60416	127	88194
6	04166	47	32638	88	61111	128	88888
7	04861	48	33333	89	61805	129	89583
8	05555	49	34027	90	62500	130	90277
9	06250	50	34722	91	63194	131	90972
10	06944	51	35416	92	63888	132	91666
11	07638	52	36111	93	64583	133	92361
12	08333	53	36805	94	65277	134	93055
13	09027	54	37500	95	65972	135	93750
14	09722	55	38194	96	66666	136	94444
15	10416	56	38888	97	67361	137	95138
16	11111	57	39583	98	68055	138	95833
17	11805	58	40277	99	68750	139	96527
18	12500	59	40972	100	69444	140	97222
19	13194	60	41666	101	70138	141	97916
20	13888	61	42361	102	70833	142	98611
21	14583	62	43055	103	71527	143	99305
22	15277	63	43750	104	72222	144	100000
23	15972	64	44444				

TABLE 43.—DECIMAL FRACTIONS OF A SQUARE FOOT IN SQUARE INCHES.

Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.
·01	1·44	·26	37·4	·51	73·4	·76	109·4
·02	2·88	·27	38·9	·52	74·9	·77	110·9
·03	4·32	·28	40·3	·53	76·3	·78	112·3
·04	5·76	·29	41·8	·54	77·8	·79	113·8
·05	7·20	·30	43·2	·55	79·2	·80	115·2
·06	8·64	·31	44·6	·56	80·6	·81	116·6
·07	10·1	·32	46·1	·57	82·1	·82	118·1
·08	11·5	·33	47·5	·58	83·5	·83	119·5
·09	13·0	·34	49·0	·59	85·0	·84	121·0
·10	14·4	·35	50·4	·60	86·4	·85	122·4
·11	15·8	·36	51·8	·61	87·8	·86	123·8
·12	17·3	·37	53·3	·62	89·3	·87	125·3
·13	18·7	·38	54·7	·63	90·7	·88	126·7
·14	20·2	·39	56·2	·64	92·2	·89	128·2
·15	21·6	·40	57·6	·65	93·6	·90	129·6
·16	23·0	·41	58·0	·66	95·0	·91	131·0
·17	24·5	·42	60·5	·67	96·5	·92	132·5
·18	25·9	·43	61·9	·68	97·9	·93	133·9
·19	27·4	·44	63·4	·69	99·4	·94	135·4
·20	28·8	·45	64·8	·70	100·8	·95	136·8
·21	30·2	·46	66·2	·71	102·2	·96	138·2
·22	31·7	·47	67·7	·72	103·7	·97	139·7
·23	33·1	·48	69·1	·73	105·1	·98	141·1
·24	34·6	·49	70·6	·74	106·6	·99	142·6
·25	36·0	·50	72·0	·75	108·0	1·00	144·0

TABLE 44.—CORRELATIVE RATES (ENGLISH).

100 lbs. per cubic foot	. . .	<div> <div>·926 ounce per cubic inch.</div> <div>24·107 cwt. per cubic yard.</div> <div>1·2053 tons per cubic yard.</div> </div>
1 cwt. per cubic yard	. . .	4·148 lbs. per cubic foot.
1 ton per cubic yard	. . .	82·963 lbs. per cubic foot.
1 grain per gallon (1 in 70,000 parts, by weight, of water)	. . .	<div>6·2321 grains per cubic foot.</div> <div>163·36 grains per cubic yard.</div> <div>220·09 grains per cubic metr</div>
1 lb. per lineal yard	. . .	·7857 ton per mile.

TABLE 51. FRENCH MEASURES OF WEIGHT.

		Grammes.		English Equivalents.	
	1 milligramme.	001	0154 grain.		
10 milligrammes.	1 centigramme.	01	1548 grain		
10 centigrammes.	1 decigramme.	01	15432 grains.		
10 decigrammes.	{ 1 GRAMME (unit of weight) }	{ }	154323 grains.		
10 grammes.	1 decagramme.	10	{ 1543235 grains. 13527 ounce.		
10 decagrammes.	1 hectogramme.	100	{ 15432349 grains. 135274 ounces.		
10 hectogrammes.	1 KILOGRAMME	1000	22016 pounds.		
100 kilogrammes.	1 metric quintal		2204621 pounds.		
10 quintals, or	{ 1 mullier, or		{ 22046212 pounds. 196841 cwts.		
1000 kilogrammes }	tonne . . .		{ 9842 ton.		

TABLE 52. -MILLIMETRES IN LINEAL INCHES.

M.M. metres.	Inches.	M.M. metres.	Inches.	M.M. metres.	Inches.	M.M. metres.	Inches.
1	0394	26	1.0236	51	2.0079	76	2.9922
2	0787	27	1.0630	52	2.0473	77	3.0315
3	1181	28	1.1024	53	2.0866	78	3.0709
4	1573	29	1.1417	54	2.1260	79	3.1103
5	1968	30	1.1811	55	2.1654	80	3.1496
6	2362	31	1.2205	56	2.2047	81	3.1890
7	2756	32	1.2598	57	2.2441	82	3.2284
8	3150	33	1.2992	58	2.2835	83	3.2677
9	3543	34	1.3386	59	2.3228	84	3.3071
10	3937	35	1.3780	60	2.3622	85	3.3465
11	4331	36	1.4173	61	2.4016	86	3.3859
12	4724	37	1.4567	62	2.4410	87	3.4252
13	5118	38	1.4961	63	2.4803	88	3.4646
14	5512	39	1.5354	64	2.5197	89	3.5040
15	5906	40	1.5748	65	2.5591	90	3.5433
16	6299	41	1.6142	66	2.5984	91	3.5827
17	6693	42	1.6536	67	2.6378	92	3.6221
18	7087	43	1.6929	68	2.6772	93	3.6614
19	7480	44	1.7323	69	2.7166	94	3.7008
20	7874	45	1.7717	70	2.7559	95	3.7402
21	8268	46	1.8110	71	2.7953	96	3.7796
22	8661	47	1.8504	72	2.8347	97	3.8189
23	9055	48	1.8898	73	2.8740	98	3.8583
24	9449	49	1.9291	74	2.9134	99	3.8977
25	9843	50	1.9685	75	2.9528	100	3.9371

TABLE 52. MILLIMETRES IN LINEAL INCHES (continued).

Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.
101	3.9731	143	5.6300	185	7.2835	227	8.9371
102	4.0138	144	5.6693	186	7.3229	228	8.9765
103	4.0532	145	5.7087	187	7.3623	229	9.0158
104	4.0925	146	5.7481	188	7.4016	230	9.0552
105	4.1319	147	5.7874	189	7.4410	231	9.0946
106	4.1713	148	5.8268	190	7.4804	232	9.1339
107	4.2106	149	5.8662	191	7.5198	233	9.1733
108	4.2500	150	5.9056	192	7.5591	234	9.2127
109	4.2894	151	5.9449	193	7.5985	235	9.2521
110	4.3287	152	5.9843	194	7.6379	236	9.2914
111	4.3681	153	6.0237	195	7.6772	237	9.3308
112	4.4075	154	6.0630	196	7.7166	238	9.3702
113	4.4469	155	6.1024	197	7.7560	239	9.4095
114	4.4862	156	6.1418	198	7.7954	240	9.4489
115	4.5256	157	6.1812	199	7.8347	241	9.4883
116	4.5650	158	6.2205	200	7.8741	242	9.5277
117	4.6043	159	6.2599	201	7.9135	243	9.5670
118	4.6437	160	6.2993	202	7.9528	244	9.6064
119	4.6831	161	6.3386	203	7.9922	245	9.6458
120	4.7225	162	6.3780	204	8.0316	246	9.6851
121	4.7619	163	6.4174	205	8.0709	247	9.7245
122	4.8012	164	6.4568	206	8.1103	248	9.7639
123	4.8406	165	6.4961	207	8.1497	249	9.8032
124	4.8800	166	6.5355	208	8.1891	250	9.8426
125	4.9193	167	6.5749	209	8.2284	251	9.8820
126	4.9587	168	6.6142	210	8.2678	252	9.9214
127	5.0000	169	6.6536	211	8.3072	253	9.9607
128	5.0394	170	6.6930	212	8.3465	254	10.0001
129	5.0788	171	6.7323	213	8.3859	255	10.0395
130	5.1182	172	6.7717	214	8.4253	256	10.0788
131	5.1575	173	6.8111	215	8.4646	257	10.1182
132	5.1969	174	6.8505	216	8.5040	258	10.1576
133	5.2363	175	6.8898	217	8.5434	259	10.1970
134	5.2756	176	6.9292	218	8.5828	260	10.2363
135	5.3150	177	6.9686	219	8.6221	261	10.2757
136	5.3544	178	7.0079	220	8.6615	262	10.3151
137	5.3938	179	7.0473	221	8.7009	263	10.3544
138	5.4331	180	7.0867	222	8.7402	264	10.3938
139	5.4725	181	7.1261	223	8.7796	265	10.4332
140	5.5119	182	7.1654	224	8.8190	266	10.4725
141	5.5512	183	7.2048	225	8.8584	267	10.5119
142	5.5906	184	7.2442	226	8.8977	268	10.5513

TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.
269	10·5907	311	12·2442	353	13·8978	395	15·5513
270	10·6300	312	12·2836	354	13·9371	396	15·5907
271	10·6694	313	12·3229	355	13·9765	397	15·6300
272	10·7088	314	12·3623	356	14·0159	398	15·6694
273	10·7481	315	12·4017	357	14·0552	399	15·7088
274	10·7875	316	12·4410	358	14·0946	400	15·7482
275	10·8269	317	12·4804	359	14·1340	401	15·7875
276	10·8663	318	12·5198	360	14·1733	402	15·8269
277	10·9056	319	12·5592	361	14·2127	403	15·8663
278	10·9450	320	12·5985	362	14·2521	404	15·9056
279	10·9844	321	12·6379	363	14·2915	405	15·9450
280	11·0237	322	12·6773	364	14·3308	406	15·9844
281	11·0361	323	12·7166	365	14·3702	407	16·0238
282	11·1025	324	12·7560	366	14·4096	408	16·0631
283	11·1419	325	12·7954	367	14·4489	409	16·1025
284	11·1812	326	12·8348	368	14·4883	410	16·1419
285	11·2206	327	12·8741	369	14·5277	411	16·1812
286	11·2600	328	12·9135	370	14·5670	412	16·2206
287	11·2993	329	12·9529	371	14·6064	413	16·2600
288	11·3387	330	12·9922	372	14·6458	414	16·2993
289	11·3781	331	13·0316	373	14·6852	415	16·3387
290	11·4174	332	13·0710	374	14·7245	416	16·3781
291	11·4568	333	13·1103	375	14·7639	417	16·4175
292	11·4962	334	13·1497	376	14·8033	418	16·4568
293	11·5356	335	13·1891	377	14·8426	419	16·4962
294	11·5749	336	13·2285	378	14·8820	420	16·5356
295	11·6143	337	13·2678	379	14·9214	421	16·5749
296	11·6537	338	13·3072	380	14·9608	422	16·6143
297	11·6930	339	13·3466	381	15·0001	423	16·6537
298	11·7324	340	13·3859	382	15·0395	424	16·6930
299	11·7718	341	13·4253	383	15·0789	425	16·7324
300	11·8111	342	13·4647	384	15·1182	426	16·7718
301	11·8505	343	13·5040	385	15·1576	427	16·8112
302	11·8899	344	13·5434	386	15·1970	428	16·8505
303	11·9292	345	13·5828	387	15·2363	429	16·8899
304	11·9686	346	13·6222	388	15·2757	430	16·9293
305	12·0080	347	13·6615	389	15·3151	431	16·9686
306	12·0473	348	13·7009	390	15·3545	432	17·0080
307	12·0867	349	13·7403	391	15·3938	433	17·0474
308	12·1261	350	13·7790	392	15·4332	434	17·0868
309	12·1655	351	13·8190	393	15·4726	435	17·1261
310	12·2048	352	13·8584	394	15·5119	436	17·1655

TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.
437	17.2049	456	17.9529	475	18.7009	494	19.4490
438	17.2142	457	17.9623	476	18.7103	495	19.4583
439	17.2236	458	18.0316	477	18.7797	496	19.5277
440	17.2330	459	18.0710	478	18.8191	497	19.5671
441	17.2423	460	18.1104	479	18.8584	498	19.6065
442	17.2517	461	18.1498	480	18.8978	499	19.6458
443	17.2611	462	18.1891	481	18.9372	500	19.6852
444	17.2705	463	18.2285	482	18.9765	550	21.6537
445	17.2798	464	18.2679	483	19.0159	600	23.6223
446	17.2892	465	18.3072	484	19.0553	650	25.5908
447	17.2986	466	18.3466	485	19.0946	700	27.5593
448	17.3079	467	18.3859	486	19.1340	750	29.5278
449	17.3173	468	18.4253	487	19.1734	800	31.4963
450	17.3267	469	18.4647	488	19.2128	850	33.4649
451	17.3361	470	18.5041	489	19.2521	900	35.4334
452	17.3454	471	18.5435	490	19.2915	950	37.4019
453	17.3548	472	18.5828	491	19.3309	1000	39.3704
454	17.3642	473	18.6222	492	19.3702		= 1
455	17.3735	474	18.6616	493	19.4096		metre.

By means of the above Table, and the following Table 53, the equivalent values of inches in centimetres and decimetres, and even in metres, may be found by simply altering the position of the decimal point. Take for example the tabular value of 2 millimetres, Table 52, and shift the decimal point successively, by one digit, towards the right-hand side; the values of two centimetres, two decimetres, and two metres are thereby expressed in inches, as follows.

2 millimetres	. . . . .	0.0787 inches.
2 centimetres	. . . . .	0.787 "
2 decimetres	. . . . .	7.87 "
2 metres	. . . . .	78.7 "

At the same time, it appears that, by selecting the tabular value of 20 millimetres, the value of its multiples are given more accurately, thus—

20 millimetres, or 2 centimetres	. . . . .	0.7874 inches.
2 decimetres	. . . . .	7.874 "
2 metres	. . . . .	78.74 "

Again —

200 millimetres, or 2 decimetres — 7·8741 inches
 2 metres — 78·741 „

Similarly, for example .

32 n.c. — 8·128 millimetres.
 3·2 „ — 81·28 „
 32·0 „ — { 812·8 „ or
 8128 metre.

Like functional expansions of the following tables of relative French and English measures and weight, are available for practice : greatly extending the utility of the tables.

TABLE 53. DECIMAL FRACTIONS OF A LINEAL INCH IN MILLIMETRES.

Inch	Milli- metres.	Inch.	Milli- metres.	Inch.	Milli- metres.	Inches.	Milli- metres.
·01	·254	·29	7·366	·57	14·478	·85	21·590
·02	·508	·30	7·620	·58	14·732	·86	21·844
·03	·762	·31	7·874	·59	14·986	·87	22·098
·04	1·016	·32	8·128	·60	15·240	·88	22·352
·05	1·270	·33	8·382	·61	15·494	·89	22·606
·06	1·524	·34	8·636	·62	15·748	·90	22·860
·07	1·778	·35	8·890	·63	16·002	·91	23·114
·08	2·032	·36	9·144	·64	16·256	■	23·368
·09	2·286	·37	9·398	·65	16·510	·93	23·622
10	2·540	·38	9·652	·66	16·764	·94	23·876
·11	2·794	·39	9·906	·67	17·018	·95	24·130
·12	3·048	·40	10·160	·68	17·272	·96	24·384
·13	3·302	·41	10·414	·69	17·526	·97	24·638
14	3·556	·42	10·668	·70	17·780	·98	24·892
·15	3·810	·43	10·922	·71	18·034	■	25·146
·16	4·064	·44	11·176	·72	18·288	1·00	25·400
·17	4·318	·45	11·430	·73	18·542	2·00	50·799
·18	4·572	·46	11·684	·74	18·796	3·00	76·190
■	4·826	·47	11·938	·75	19·050	4·00	101·596
·20	5·080	·48	12·192	·76	19·304	5·00	126·998
·21	5·334	·49	12·446	·77	19·558	6·00	152·397
·22	5·588	·50	12·700	·78	19·812	7·00	177·797
·23	5·842	·51	12·954	·79	20·066	8·00	203·196
·24	6·096	·52	13·208	·80	20·320	9·00	228·596
·25	6·350	·53	13·462	·81	20·574	10·00	253·995
·26	6·604	·54	13·716	·82	20·828	11·00	279·395
·27	6·858	·55	13·970	·83	21·082	12·00	304·795
·28	7·112	·56	14·224	·84	21·336	1 foot	

TABLE 54.—VULGAR FRACTIONS OF A LINEAL INCH IN MILLIMETRES.

Eighths of an Inch	Millimetres	Eighths of an Inch	Millimetres	Eighths of an Inch	Millimetres
1	3.175	4	12.700	7	22.225
2	6.350	5	15.875	8	25.400
3	9.525	6	19.050		
Twelfths of an Inch	Millimetres	Twelfths of an Inch	Millimetres	Twelfths of an Inch	Millimetres
1	2.117	5	10.583	9	19.050
2	4.233	6	12.700	10	21.166
3	6.350	7	14.816	11	23.283
4	8.466	8	16.933	12	25.400
Sixteenths of an Inch	Millimetres	Sixteenths of an Inch	Millimetres	Sixteenths of an Inch	Millimetres
1	1.587	7	11.112	13	20.637
3	4.762	9	14.287	15	23.812
5	7.937	11	17.462		
Thirty-seconds of an Inch	Millimetres	Thirty-seconds of an Inch	Millimetres	Thirty-seconds of an Inch	Millimetres
1	0.794	13	10.315	25	19.843
3	2.381	15	11.903	27	21.431
5	3.969	17	13.493	29	23.018
7	5.556	19	15.081	31	24.606
9	7.144	21	16.668		
11	8.731	23	18.256		
Sixty-fourths of an Inch	Millimetres	Sixty-fourths of an Inch	Millimetres	Sixty-fourths of an Inch	Millimetres
1	0.397	23	9.128	45	17.859
3	1.191	25	10.092	47	18.653
5	1.984	27	10.717	49	19.447
7	2.778	29	11.500	51	20.240
9	3.572	31	12.286	53	21.034
11	4.365	33	13.071	55	21.828
13	5.159	35	13.856	57	22.621
15	5.953	37	14.644	59	23.415
17	6.747	39	15.428	61	24.209
19	7.540	41	16.212	63	25.000
21	8.334	43	17.005		

TABLE 35.—METRES IN LINEAL FEET AND IN YARDS.

Metres.	Feet.	Yards.	Metres.	Feet.	Yards.
1	3.2809	1.0936	44	144.3596	48.1193
2	6.5618	2.1872	45	147.6405	49.2129
3	9.8427	3.2809	46	150.9214	50.3065
4	13.1236	4.3745	47	154.2023	51.4001
5	16.4045	5.4681	48	157.4832	52.4938
6	19.6854	6.5617	■	160.7641	53.5874
7	22.9663	7.6553	50	164.0450	54.6810
8	26.2472	8.7490	51	167.3259	55.7746
9	29.5281	9.8426	52	170.6068	56.8682
10	32.8090	10.9362	■	173.8877	57.9619
11	36.0899	12.0298	54	177.1686	59.0555
12	39.3708	13.1234	55	180.4495	60.1491
13	42.6517	14.2171	56	183.7304	61.2427
14	45.9326	15.3107	57	187.0113	62.3363
15	49.2135	16.4043	58	190.2922	63.4300
16	52.4944	17.4979	59	193.5731	64.5236
17	55.7753	18.5915	60	196.8540	65.6172
18	59.0562	19.6852	61	200.1349	66.7108
19	62.3371	20.7788	62	203.4158	67.8044
20	65.6180	21.8724	63	206.6967	68.8981
21	68.8989	22.9660	64	209.9776	69.9917
22	72.1798	24.0596	65	213.2585	71.0853
23	75.4607	25.1533	66	216.5394	72.1789
24	78.7416	26.2469	67	219.8203	73.2725
25	82.0225	27.3405	68	223.1012	74.3662
26	85.3034	28.4341	69	226.3821	75.4598
27	88.5843	29.5277	70	229.6630	76.5534
28	91.8652	30.6214	71	232.9439	77.6470
29	95.1461	31.7150	72	236.2248	78.7406
30	98.4270	32.8086	73	239.5057	79.8343
31	101.7079	33.9022	74	242.7866	80.9279
32	104.9888	34.9958	75	246.0675	82.0215
33	108.2697	36.0895	76	249.3484	83.1151
■	111.5506	37.1831	77	252.6293	84.2087
35	114.8315	38.2767	78	255.9102	85.3024
36	118.1124	39.3703	79	259.1911	86.3960
37	121.3933	40.4639	80	262.4720	87.4896
38	124.6742	41.5576	81	265.7529	88.5832
39	127.9551	42.6512	82	269.0338	89.6768
40	131.2360	43.7448	■	272.3147	90.7705
41	134.5169	44.8384	■	275.5956	91.8641
42	137.7978	45.9320	85	278.8765	92.9577
43	141.0787	47.0257	86	282.1574	94.0513

TABLE 55.—METRES IN LINEAL FEET AND IN YARDS
(continued).

Metres.	Feet.	Yards.	Metres.	Feet.	Yards.
87	285.4383	95.1419	94	308.4046	102.8003
88	288.7192	96.2380	95	311.6855	103.8939
89	292.0001	97.3322	96	314.9664	104.9875
90	295.2810	98.4258	97	318.2473	106.0811
91	298.5619	99.5194	98	321.5282	107.1748
92	301.8428	100.6150	99	324.8091	108.2684
93	305.1237	101.7067	100	328.0900	109.3620

TABLE 56.—LINEAL FEET IN METRES.

Feet.	Metres.	Feet.	Metres.	Feet.	Metres.	Feet.	Metres.
1	.3048	26	7.9248	51	15.5448	76	23.1648
2	.6096	27	8.2296	52	15.8496	77	23.4696
3	.9144	28	8.5344	53	16.1544	78	23.7744
4	1.2192	29	8.8392	54	16.4592	79	24.0792
5	1.5240	30	9.1440	55	16.7640	80	24.3840
6	1.8288	31	9.4488	56	17.0688	81	24.6888
7	2.1336	32	9.7536	57	17.3736	82	24.9936
8	2.4384	33	10.0584	58	17.6784	83	25.2984
9	2.7432	34	10.3632	59	17.9832	84	25.6032
10	3.0480	35	10.6680	60	18.2880	85	25.9080
11	3.3528	36	10.9728	61	18.5928	86	26.2128
12	3.6576	37	11.2776	62	18.8976	87	26.5176
13	3.9624	38	11.5824	63	19.2024	88	26.8224
14	4.2672	39	11.8872	64	19.5072	89	27.1272
15	4.5720	40	12.1920	65	19.8120	90	27.4320
16	4.8768	41	12.4968	66	20.1168	91	27.7368
17	5.1816	42	12.8016	67	20.4216	92	28.0416
18	5.4864	43	13.1064	68	20.7264	93	28.3464
19	5.7912	44	13.4112	69	21.0312	94	28.6512
20	6.0960	45	13.7160	70	21.3360	95	28.9560
21	6.4008	46	14.0208	71	21.6408	96	29.2608
22	6.7056	47	14.3256	72	21.9456	97	29.5656
23	7.0104	48	14.6304	73	22.2504	98	29.8704
24	7.3152	49	14.9352	74	22.5552	99	30.1752
25	7.6200	50	15.2400	75	22.8600	100	30.4800

TABLE 55. METRES IN LINEAL FEET AND IN YARDS.

Metres.	Feet.	Yards.	Metres.	Feet.	Yards.
1	3.2809	1.0936	44	144.8596	48.1133
2	6.5618	2.1872	45	147.3405	49.2129
3	9.8427	3.2809	46	150.3214	50.3065
4	13.1236	4.3745	47	154.2023	51.4001
5	16.4045	5.4681	48	157.1832	52.4938
6	19.6854	6.5617	49	160.7641	53.5874
7	22.9663	7.6553	50	164.0450	54.6810
8	26.2472	8.7490	51	167.3259	55.7746
9	29.5281	9.8426	52	170.6068	56.8682
10	32.8090	10.9362	53	173.8877	57.9619
11	36.0899	12.0298	54	177.1686	59.0555
12	39.3708	13.1234	55	180.4495	60.1491
13	42.6517	14.2171	56	183.7304	61.2427
14	45.9326	15.3107	57	187.0113	62.3363
15	49.2135	16.4043	58	190.2922	63.4300
16	52.4944	17.4979	59	193.5731	64.5236
17	55.7753	18.5915	60	196.8540	65.6172
18	59.0562	19.6852	61	200.1349	66.7108
19	62.3371	20.7788	62	203.4158	67.8044
20	65.6180	21.8724	63	206.6967	68.8981
21	68.8989	22.9660	64	209.9776	69.9917
22	72.1798	24.0596	65	213.2585	71.0853
23	75.4607	25.1533	66	216.5394	72.1789
24	78.7416	26.2469	67	219.8203	73.2725
25	82.0225	27.3405	68	223.1012	74.3662
26	85.3034	28.4341	69	226.3821	75.4598
27	88.5843	29.5277	70	229.6630	76.5534
28	91.8652	30.6214	71	232.9439	77.6470
29	95.1461	31.7150	72	236.2248	78.7406
30	98.4270	32.8086	73	239.5057	79.8343
31	101.7079	33.9022	74	242.7866	80.9279
32	104.9888	34.9958	75	246.0675	82.0215
33	108.2697	36.0895	76	249.3484	83.1151
34	111.5506	37.1831	77	252.6293	84.2087
35	114.8315	38.2767	78	255.9102	85.3024
36	118.1124	39.3703	79	259.1911	86.3960
37	121.3933	40.4639	80	262.4720	87.4896
38	124.6742	41.5576	81	265.7529	88.5832
39	127.9551	42.6512	82	269.0338	89.6768
40	131.2360	43.7448	83	272.3147	90.7705
41	134.5169	44.8384	84	275.5956	91.8641
42	137.7978	45.9320	85	278.8765	92.9577
43	141.0787	47.0257	86	282.1574	94.0513

TABLE 55. -METRES IN LINEAL FEET AND IN YARDS
(continued).

Metres.	Feet	Yards.	Metres.	Feet.	Yards.
87	285.4383	95.1410	94	308.4046	102.8003
88	288.7192	96.2386	95	311.6855	103.8939
89	292.0001	97.3322	96	314.9664	104.9875
90	295.2810	98.4258	97	318.2473	106.0811
91	298.5619	99.5194	98	321.5282	107.1748
92	301.8428	100.6130	99	324.8091	108.2684
93	305.1237	101.7067	100	328.0900	109.3620

TABLE 56. - LINEAL FEET IN METRES.

Feet.	Metres.	Feet.	Metres.	Feet.	Metres.	Feet.	Metres.
1	.3048	26	7.9248	51	17.5448	76	23.1648
2	.6096	27	8.2296	52	17.8496	77	23.4696
3	.9144	28	8.5344	53	16.1544	78	23.7744
4	1.2192	29	8.8392	54	16.4592	79	24.0792
5	1.5240	30	9.1440	55	16.7640	80	24.3840
6	1.8288	31	9.4488	56	17.0688	81	24.6888
7	2.1336	32	9.7536	57	17.3736	82	24.9936
8	2.4384	33	10.0584	58	17.6784	83	25.2984
9	2.7432	34	10.3632	59	17.9832	84	25.6032
10	3.0480	35	10.6680	60	18.2880	85	25.9080
11	3.3528	36	10.9728	61	18.5928	86	26.2128
12	3.6576	37	11.2776	62	18.8976	87	26.5176
13	3.9624	38	11.5824	63	19.2024	88	26.8224
14	4.2672	39	11.8872	64	19.5072	89	27.1272
15	4.5720	40	12.1920	65	19.8120	90	27.4320
16	4.8768	41	12.4968	66	20.1168	91	27.7368
17	5.1816	42	12.8016	67	20.4216	92	28.0416
18	5.4864	43	13.1064	68	20.7264	93	28.3464
19	5.7912	44	13.4112	69	21.0312	94	28.6512
20	6.0960	45	13.7160	70	21.3360	95	28.9560
21	6.4008	46	14.0208	71	21.6408	96	29.2608
22	6.7056	47	14.3256	72	21.9456	97	29.5656
23	7.0104	48	14.6304	73	22.2504	98	29.8704
24	7.3152	49	14.9352	74	22.5552	99	30.1752
25	7.6200	50	15.2400	75	22.8600	100	30.4800

TABLE 57. — LINEAL YARDS IN METRES.

Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.
1	0.9144	26	23.7741	51	46.6339	76	69.4930
2	1.8288	27	24.6885	52	47.5483	77	70.4080
3	2.7432	28	25.6029	53	48.4627	78	71.3224
4	3.6576	29	26.5173	54	49.3771	79	72.2368
5	4.5719	30	27.4317	55	50.2914	80	73.1512
6	5.4863	31	28.3461	56	51.2058	81	74.0656
7	6.4007	32	29.2605	57	52.1202	82	74.9800
8	7.3151	33	30.1749	58	53.0346	83	75.8944
9	8.2295	34	31.0893	59	53.9490	84	76.8088
10	9.1439	35	32.0036	60	54.8634	85	77.7231
11	10.0583	36	32.9180	61	55.7778	86	78.6375
12	10.9727	37	33.8324	62	56.6922	87	79.5519
13	11.8871	38	34.7468	63	57.6066	88	80.4663
14	12.8015	39	35.6612	64	58.5210	89	81.3807
15	13.7158	40	36.5756	65	59.4353	90	82.2951
16	14.6302	41	37.4900	66	60.3497	91	83.2095
17	15.5446	42	38.4044	67	61.2641	92	84.1239
18	16.4590	43	39.3188	68	62.1785	93	85.0383
19	17.3734	44	40.2332	69	63.0929	94	85.9527
20	18.2878	45	41.1475	70	64.0073	95	86.8670
21	19.2022	46	42.0619	71	64.9217	96	87.7814
22	20.1166	47	42.9763	72	65.8361	97	88.6958
23	21.0310	48	43.8907	73	66.7505	98	89.6102
24	21.9454	49	44.8051	74	67.6649	99	90.5246
25	22.8598	50	45.7195	75	68.5792	100	91.4390

TABLE 58. KILOGRAMMES IN POUNDS.

Kilos.	Pounds.	Kilos.	Pounds.	Kilos.	Pounds.	Kilos.	Pounds.
1	2.2046	13	28.6601	25	55.1155	37	81.5710
2	4.4092	14	30.8647	26	57.3201	38	83.7756
3	6.6139	15	33.0693	27	59.5248	39	85.9802
4	8.8185	16	35.2739	28	61.7294	40	88.1848
5	11.0231	17	37.4786	29	63.9340	41	90.3894
6	13.2277	18	39.6832	30	66.1386	42	92.5940
7	15.4323	19	41.8878	31	68.3433	43	94.7987
8	17.6370	20	44.0924	32	70.5479	44	97.0033
9	19.8416	21	46.2970	33	72.7525	45	99.2079
10	22.0462	22	48.5017	34	74.9571	46	101.4125
11	24.2508	23	50.7063	35	77.1617	47	103.6171
12	26.4555	24	52.9109	36	79.3663	48	105.8217

TABLE 60. SQUARE METRES IN SQUARE FEET AND SQUARE YARDS (continued).

Square Metres.	Square Feet.	Square Yards.	Square Metres.	Square Feet.	Square Yards.
83	898.4220	99.2680	93	999.2990	110.5320
84	904.1861	100.4540	94	1001.0532	111.2280
85	914.9602	101.6600	95	1011.8273	112.4240
86	925.7143	102.8760	96	1022.6014	113.6200
87	936.4784	104.0520	97	1033.3755	114.8160
88	947.2425	105.2480	98	1044.1496	116.0120
89	958.0067	106.4440	99	1054.9238	117.2080
90	968.7708	107.6400	100	1065.6979	118.4040
91	979.5349	108.8360		1076.4720	119.6000

TABLE 61.—SQUARE FEET IN SQUARE METRES.

Square Feet.	Square Metres.	Square Feet.	Square Metres.	Square Feet.	Square Metres.	Square Feet.	Square Metres.
1	.0929	26	2.4154	51	4.7380	76	7.0605
2	.1858	27	2.5083	52	4.8309	77	7.1534
3	.2787	28	2.6012	53	4.9238	78	7.2463
4	.3716	29	2.6941	54	5.0167	79	7.3392
5	.4645	30	2.7870	55	5.1096	80	7.4321
6	.5574	31	2.8799	56	5.2025	81	7.5250
7	.6503	32	2.9728	57	5.2954	82	7.6179
8	.7432	33	3.0657	58	5.3883	83	7.7108
9	.8361	34	3.1586	59	5.4812	84	7.8037
10	.9290	35	3.2515	60	5.5741	85	7.8966
11	1.0219	36	3.3444	61	5.6670	86	7.9895
12	1.1148	37	3.4373	62	5.7599	87	8.0824
13	1.2077	38	3.5302	63	5.8528	88	8.1753
14	1.3006	39	3.6231	64	5.9457	89	8.2682
15	1.3935	40	3.7160	65	6.0386	90	8.3611
16	1.4864	41	3.8089	66	6.1315	91	8.4540
17	1.5793	42	3.9018	67	6.2244	92	8.5469
18	1.6722	43	3.9947	68	6.3173	93	8.6398
19	1.7651	44	4.0876	69	6.4102	94	8.7327
20	1.8580	45	4.1805	70	6.5031	95	8.8256
21	1.9509	46	4.2734	71	6.5960	96	8.9185
22	2.0438	47	4.3663	72	6.6889	97	9.0114
23	2.1367	48	4.4592	73	6.7818	98	9.1043
24	2.2296	49	4.5521	74	6.8747	99	9.1972
25	2.3225	50	4.6450	75	6.9676	100	9.2901

TABLE 62. SQUARE YARDS IN SQUARE METRES.

Square Yards.	Square Metres.	Square Yards.	Square Metres.	Square Yards.	Square Metres.	Square Yards.	Square Metres.
1	8361	26	217589	51	426417	76	65448
2	16722	27	225750	52	434778	77	663806
3	25083	28	234111	53	443139	78	673167
4	33444	29	242472	54	451500	79	682528
5	41806	30	250834	55	459861	80	691889
6	50167	31	259195	56	468223	81	701251
7	58528	32	267556	57	476584	82	710612
8	66889	33	275917	58	484945	83	719973
9	75250	34	284278	59	493306	84	729334
10	83611	35	292639	60	501667	85	738695
11	91972	36	301000	61	510028	86	748056
12	100333	37	309361	62	518389	87	757417
13	108695	38	317723	63	526751	88	766778
14	117056	39	326084	64	535112	89	776139
15	125417	40	334445	65	543473	90	785500
16	133778	41	342806	66	551834	91	794861
17	142139	42	351167	67	560195	92	804222
18	150500	43	359528	68	568556	93	813583
19	158861	44	367889	69	576917	94	822944
20	167222	45	376250	70	585278	95	832305
21	175583	46	384611	71	593639	96	841666
22	183945	47	392973	72	601999	97	851027
23	192306	48	401334	73	610362	98	860388
24	200667	49	409695	74	618723	99	869749
25	209028	50	418056	75	627085	100	879110

TABLE 63. -CUBIC METRES IN CUBIC FEET AND CUBIC YARDS.

Cubic Metres.	Cubic Feet.	Cubic Yards.	Cubic Metres.	Cubic Feet.	Cubic Yards.
1	35.3156	1.3080	10	353.1560	13.0800
2	70.6312	2.6160	11	388.4716	14.3880
3	105.9468	3.9240	12	423.7872	15.6960
4	141.2624	5.2320	13	459.1028	17.0040
5	176.5780	6.5400	14	494.4184	18.3120
6	211.8936	7.8480	15	529.7340	19.6200
7	247.2092	9.1560	16	565.0496	20.9280
8	282.5248	10.4640	17	600.3652	22.2360
9	317.8404	11.7720	18	635.6808	23.5440

TABLE 63 - CUBIC METRES IN CUBIC FEET AND CUBIC YARDS (continued).

Cubic Metres	Cubic Feet	Cubic Yards	Cubic Metres	Cubic Feet	Cubic Yards
19	670.9964	24.8520	60	2118.9361	78.4800
20	706.3120	26.1600	61	2154.2516	79.7880
21	741.6276	27.4680	62	2189.5672	81.0960
22	776.9432	28.7760	63	2224.8828	82.4040
23	812.2588	30.0840	64	2260.1984	83.7120
24	847.5744	31.3920	65	2295.5140	85.0200
25	882.8900	32.7000	66	2330.8296	86.3280
26	918.2056	34.0080	67	2366.1452	87.6360
27	953.5212	35.3160	68	2401.4608	88.9440
28	988.8368	36.6240	69	2436.7764	90.2520
29	1024.1524	37.9320	70	2472.0920	91.5600
30	1059.4680	39.2400	71	2507.4076	92.8680
31	1094.7836	40.5480	72	2542.7232	94.1760
32	1130.0992	41.8560	73	2578.0388	95.4840
33	1165.4148	43.1640	74	2613.3544	96.7920
34	1200.7304	44.4720	75	2648.6700	98.1000
35	1236.0460	45.7800	76	2683.9856	99.4080
36	1271.3616	47.0880	77	2719.3012	100.7160
37	1306.6772	48.3960	78	2754.6168	102.0240
38	1341.9928	49.7040	79	2789.9324	103.3320
39	1377.3084	51.0120	80	2825.2480	104.6400
40	1412.6240	52.3200	81	2860.5636	105.9480
41	1447.9396	53.6280	82	2895.8792	107.2560
42	1483.2552	54.9360	83	2931.1948	108.5640
43	1518.5708	56.2440	84	2966.5104	109.8720
44	1553.8864	57.5520	85	3001.8260	111.1800
45	1589.2020	58.8600	86	3037.1416	112.4880
46	1624.5176	60.1680	87	3072.4572	113.7960
47	1659.8332	61.4760	88	3107.7728	115.1040
48	1695.1488	62.7840	89	3143.0884	116.4120
49	1730.4644	64.0920	90	3178.4040	117.7200
50	1765.7800	65.4000	91	3213.7196	119.0280
51	1801.0956	66.7080	92	3249.0352	120.3360
52	1836.4112	68.0160	93	3284.3508	121.6440
53	1871.7268	69.3240	94	3319.6664	122.9520
54	1907.0424	70.6320	95	3354.9820	124.2600
55	1942.3580	71.9400	96	3390.2976	125.5680
56	1977.6736	73.2480	97	3425.6132	126.8760
57	2012.9892	74.5560	98	3460.9288	128.1840
58	2048.3048	75.8640	99	3496.2444	129.4920
59	2083.6204	77.1720	100	3531.5600	130.8000

1 cubic yard	$\frac{3}{4}$ cubic metre (2 per cent. more).
1 cubic metre	$1\frac{1}{3}$ cubic yard ($1\frac{1}{3}$ per cent. less).
1 cubic metre	35 $\frac{1}{2}$ cub. feet (95 per cent. less).
1 litre	$1\frac{1}{4}$ pints fully.
1 gallon	$4\frac{1}{2}$ litres fully.
1 cubic foot	28.3 litres.
1 cubic metre of water .	1 ton nearly.
1 gramme	15 $\frac{1}{2}$ grains nearly.
1 kilogramme	2.2 pounds fully.
1000 kilogrammes } 1 metric ton }	1 ton nearly.
1 hundredweight	51 kilogrammes nearly.

TABLE 67.—FRENCH AND ENGLISH COMPOUND EQUIVALENTS.

1 kilogramme per lineal metre	672 pound per lineal foot. 2.016 pounds per yard.
1000 kilogrammes (1 tonne) per metre	30.1 ton per foot.
1 kilogramme per kilometre	3.348 pounds per mile.
1000 kilogrammes (1 tonne) per kilometre	1.584 tons per mile.
1 kilogramme per square millimetre	1422.32 pounds per square inch. 635 ton per square inch.
1 kilogramme per square centimetre	14.2232 pounds per square inch.
1 kilogramme per square decimetre	20.4776 pounds per square foot.
1 kilogramme per square metre	1.8430 pounds per square yard.
1000 kilogrammes (1 tonne) per square metre . . . . .	.8229 ton per square yard.
1 kilogramme per tonne	2.240 pounds per ton.
1 kilogramme per tonne per kilometre	3.6042 pounds per ton per mile.
1 litre of water at 4° C. per tonne per kilometre	3.6042 pounds per ton per mile. 3599 gallon at 62° F. per ton per mile.
1 gramme per square millimetre	1.422 pounds per square inch.
1 gramme per square centimetre . . . . .	.01422 pound per square inch.
1 kilogramme per cubic metre	1.686 pounds per cubic yard. .0624 pound per cubic foot.
1000 kilogrammes (1 tonne) per cubic metre . . . . .	.984 ton per cubic metre.
per cubic metre . . . . .	.752 ton per cubic yard.

1 cubic metre per kilogramme	16·019 cubic feet per pound.
1 cubic metre per tonne	{ 1·329 cubic yards per ton. 35·882 cubic feet per ton.
1 cubic metre per kilometre	2·105 cubic yards per mile.
1 gramme per litre	73·09 grains per gallon.
1 kilogramme per litre	10·4382 pounds per gallon.
1 cubic metre per lineal metre	{ 1·196 cubic yards per lineal yard.
1 cubic metre per square metre	3·281 cubic feet per square foot.
1 litre per square metre	·0204 gallon per square foot.
1 cubic metre per hectare	{ ·405 cubic metre per acre. ·529 cubic yard per acre. 89·065 gallons per acre.
1 kilogrammetre	7·233 foot-pounds.
1 tonne-metre	3 foot-tons.
1 cheval vapeur, or cheval (75k x m per second)	{ ·9863 horse-power.
1 kilogramme per cheval	2·235 pounds per horse-power.
1 square metre per cheval	{ 10·913 square feet per horse- power.
1 cubic metre per cheval	{ 35·806 cubic feet per horse- power.
1 calorie or French unit of heat	{ 3·968 English heat-units.
French mechanical equiva- lent of heat (425 kilogram- metres)	{ 3074 foot-pounds per unit.
1 calorie per square metre	·369 heat-unit per square foot.
1 calorie per kilogramme	1·800 heat-units per pound.
1 franc per kilogramme	{ ·360 shillings per pound. £40·32 per ton.
1 franc per quintal	·403 shillings per cwt.
1 franc per tonne	{ ·484 penny per cwt. ·806 shilling per ton.
1 franc per metre	{ ·726 shilling per yard. 8·709 pence per yard.
1 franc per kilometre	{ £0·6386 per mile. 15·326 pence per mile.
1 franc per square metre	{ 7·963 pence per square yard. ·6636 shilling per square yard.
1 franc per cubic metre	7·281 pence per cubic yard.
1 franc per litre	3·606 shillings per gallon.
1 franc per hectolitre	1·893 shillings per hogshead.

TABLE 68.—ENGLISH AND FRENCH COMPOUND EQUIVALENTS.

1 pound per lineal foot . . .	{ 1 488 kilogrammes per lineal metre.
1 pound per yard . . .	{ 496 kilogramme per metre.
1 ton per foot . . .	{ 3333·333 kilogrammes ($3\frac{1}{3}$ tons) per metre.
1 ton per yard . . .	{ 1111·111 kilogrammes ($1\frac{1}{3}$ tons) per metre.
1 pound per mile . . .	{ 2818 kilogrammes per kilo- metre.
1 ton per mile . . .	{ 6913 tonne per kilometre.
1 pound per ton . . .	{ 4464 kilogramme per tonne.
1 pound per ton per mile . . .	{ 2774 kilogramme per tonne per kilometre.
	{ 0·70307 kilogramme persquare centimetre.
1 pound per square inch . . .	{ 7031 gramme per square milli- metre.
	{ 5·170 centimetres of mercury at 0° C.
1 atmosphere (14·7 pounds per square inch) . . .	{ 1·0335 kilogrammes per square centimetre.
1000 pounds per square inch . . .	{ 703077 kilogramme per square millimetre.
2000 pounds per square inch . . .	{ 1·406154 kilogrammes per square millimetre.
1 ton per square inch . . .	{ 1·575 kilogrammes per square millimetre.
1 pound per square foot . . .	{ 4·883 kilogrammes per square metre.
1000 pounds per square foot . . .	{ 4882·317 kilogrammes per square metre.
1 ton per square foot . . .	{ 10·936 tonnes per square metre.
1000 pounds per square yard . . .	{ 542·500 kilogrammes per square metre.
1 ton per square yard . . .	{ 1·215 tonnes per square metre.
1 pound per cubic yard . . .	{ 5933 kilogramme per cubic metre.
1 pound per cubic foot . . .	{ 16·020 kilogrammes per cubic metre.
1 ton per cubic yard . . .	{ 1·329 tonnes per cubic metre.
1 cubic yard per pound . . .	{ 1·6855 cubic metres per kilo- gramme.
1 cubic yard per ton . . .	{ 7525 cubic metre per tonne.
1 cubic yard per mile . . .	{ 4750 cubic metre per kilometre.

1 grain per gallon	01426 gramme per litre.
1 pound per gallon	09983 kilogramme per litre.
1 cubic yard per lineal yard	836 cubic metre per lineal metre.
1 cubic foot per square foot	3048 cubic metres per square metre.
1 gallon per square foot	4895 litres per square metre.
1 cubic metre per acre	2471 cubic metres per hectare.
1 cubic yard per acre	1902 cubic metres per hectare.
1000 gallons per acre	11226 cubic metres per hectare.
1 foot-pound	1382 kilogrammetre.
1 foot-ton	3333 tonne-metre.
1 horse-power	10139 cheval.
1 pound per horse-power	447 kilogramme per cheval.
1 square foot per horse-power	0196 square metre per cheval.
1 cubic foot per horse-power	0279 cubic metre per cheval.
1 English unit of heat, or heat-unit	252 calorie.
English mechanical equivalent to one heat-unit (772 foot-pounds)	1067 kilogrammetres.
1 English heat-unit per square foot	2713 calories per square metre.
1 English heat-unit per pound	3 calorie per kilogramme.
1 penny per pound	231 franc per kilogramme.
1 shilling per pound	2772 franc per kilogramme.
1 shilling per cent. or	24802 francs per tonne
£1 per ton	248 francs per quintal.
1 shilling per yard	1378 francs per metre.
1 penny per mile	0652 franc per kilometre
£1 per mile	1566 francs per kilometre.
1 shilling per square yard	1510 francs per square metre.
£1 per square yard	30194 francs per square metre.
1 penny per cubic foot	3708 francs per cubic metre.
1 penny per cubic yard	197 franc per cubic metre
1 shilling per cubic yard	1648 francs per cubic metre.
£1 per cubic yard	32962 francs per cubic metre.
1 shilling per hogshead	528 franc per hectolitre.
1 penny per gallon	0231 franc per litre.

EUROPE.

Austria-Hungary.

Length. 1 Fuss = 10371 feet; 2 Fuss = 1 Elle = 20742 feet;
 6 Fuss = 1 Klafter = 62226 feet; 1000 Klafter = 1 Meil
 4714 miles.

Surface. 1 square Klafter = 38.7225 square feet = 4.302 square yards; 1600 square Klafter = 1 Joch = 1.4223 acres.

Volume. 1 cubic Klafter = 240.94 cubic feet = 8.924 cubic yards.

Capacity, dry. 1 Achtel = 1.6920 gallons; 2 Achtel = 1 Vierte = 3.3840 gallons = 1230 bushels; 4 Viertel = 1 Metze = 1.6918 bushels.

Capacity, liquid. 1 Kanne = 1.2457 pints; 2 Kannen = 1 Mass = 2.4914 quarts; 10 Mass = 1 Viertel = 3.1148 gallons; 4 Viertel = 1 Eimer = 12.4572 gallons.

Weight. 1 Pfund = 1.2347 pounds; 100 Pfund = 1 Centner = 123.47 pounds = 1.024 hundredweights.

The French metric system of weights and measures is legal in Austria-Hungary.

Belgium.

The French metric system is in force in Belgium. The same *unit* is substituted for metre, *litre* for litre, *kilogramm* for kilogramme.

Denmark.

Length. 1 Fod = 1.0297 feet; 6 Fod = 1 Favn = 6.1783 feet; 1 Mil = 4.68055 miles.

Surface. 1 square Fod = 1.0603 square feet; 144 square Fod = 1 square Rod = 10.666 square yards.

Volume. 1 cubic Fod = 1.0918 cubic feet. The Favn of firewood = 6 Fod x 6 Fod x 2 Fod = 72 cubic Fod = 78.60 cubic feet.

Capacity, liquid. 38 Potter = 1 Anker = 8.0709 gallons; 136 Potter = 1 Tinde = 28.885 gallons.

Capacity, dry. 1 Tinde or barrel of grain or salt = 3.823 bushels; barrel of coal = 4.7 bushels.

Weight. 100 Kvinten = 1 Pund = 1.1023 pounds; 100 Pund = 1 Centner = 110.23 pounds; 40 Centner = 1 Last = 4.4084 tons; 1 Skip-last = 2.5390 tons.

Germany

The French metrical system of weights and measures came into force in Germany, on January 1, 1872.

Length. The metre is known as the *Stab*; the centimetre as the *Neu Zoll*; the kilometre is the same. 7 kilometres = 1 mile = 4.37 English miles.

Surface. The square metre is the *Quadrat stab*; the are is the *Ar*; the hectare is the *Hektar*. The square kilometre is the *Quadrat* = 247.11 acres.

Volume. 2 Schoppen = 1 Kanne = 1 litre; 50 Kannen = 1 scheffel = 50 litres = 1.376 bushels; 2 scheffels = 1 Fass (cask) = 1 hectolitre = 22.01 gallons.

Weight. The milligramme, centigramme and decigramme

are respectively the *Milligram*, *Centigramm*, and *Decigramm*.
 100 decigrammes = 1 Neutoth 10 grammes = 35273 ounce;
 50 neutoths = 1 Pfund $\frac{1}{2}$ kilogramme = 11023 pounds; 100
 pfunds = 1 Centner 50 kilogrammes = 11023 pounds; 20
 centners = 1 tonne = 2204 6 pounds or 9842 ton.

Greece.

The French metric system is employed in Greece. The metre is the *percheus*, the kilometre the *stadion*, the are the *stremma*; the litre the *litra*, the gramme the *drachmá*, $1\frac{1}{2}$ kilogrammes = 1 Muá; $1\frac{1}{2}$ quintals = 1 tolanton; $1\frac{1}{2}$ tonneaux = 1 Tono = 29526 hundredwt.

Italy.

The French metric system is in force. The metre is known as the *metro*; the kilometre, *chilometro*; the are, *aro*; the hectare, *ettaro*; the litre, *litro*; the gramme, *gramo*; the tonne, *tonnellata*.

Netherlands.

The French metric system is in force in the Netherlands. The French nomenclature is followed, with but trifling variations.

Portugal.

The French metric system is the legal standard. The old measures principally still in use are, the libra = 1012 pounds; the almude of Lisbon = 37 gallons; the almude of Oporto = 56 gallons; the alquiere = 36 bushel, the moio = 278 quarters.

Roumania.

The French metric system is in force in Roumania. Turkish weights and measures are largely in use by the people.

Russia.

Length. 1 Vershok = 175 inches; 16 Vershoks = 1 Arschin = 28 inches; 3 Arschines = 1 Sajene = 7 feet; 500 Sajenes = 1 Verst = 3500 feet or 6629 mile. The English foot decimally divided is the ordinary standard of length. The Rhin Fuss (= 103 English feet) is used in calculating export duties on timber.

Surface. 1 square Arschine = 5444 square feet; 9 square arschines = 1 square sajene = 49 square feet; 2400 square sajenes = 1 Desatine = 270 acres. For earthworks, masonry, &c. the sajene is divided into tenths (*dessiatka*), hundredths (*Sotka*), and thousandths (*tisiatcka*). These are squared or cubed for superficial and cubic measurements.

Capacity, liquid. 1 Tsharkey = 2164 pint; 10 tsharkeys = 1 Krushka = 10820 quarts; 100 tsharkeys = 1 Vedro = 2700 gallons; 3 vedros = 1 anker = 8147 gallons; 40 Vedros = 1 Sarokowa, a Boslka = 108196 gallons.

Capacity, dry. (Gran) 1 Tschetwert = 57704 bushels (usually reckoned at 5½ bushels); 16 Tschetwerts = 1 Last = 115408 quarters. 100 Tschetwerts are usually reckoned equal to 72 quarters; they are exactly 721308 quarters.

Weight. 12 lanas = 32 lottis = 96 Zolotnicks = 1 Funt or pound = 90285 English pound = 14446 ounces; 40 pounds = 1 Pood = 36114 English pounds; 620257 Poods = 1 English ton; 1 ship-last = 189 English tons.

Servia.

The French metric system has been in use in Servia since 1883. The old Turkish and Austrian weights and measures still linger in outlying districts.

Spain.

The French metric system has been established in Spain since 1859. The metre is the *metro*; the litre, the *litro*; the gramme the *gramo*; the are, the *area*. The old system continues largely in use.

Length. 12 lineas = 1 pulgada = 927 inch; 12 pulgadas = 1 Pies de Burgos = 9273 foot; 3 Pies = 1 Vará = 2782 feet; 5000 Varas = 1 Legua (Castilian) = 26345 miles; 8000 Varas = 1 Legua (Spanish) = 42151 miles.

Surface. 1 square Vara = 860 square yard; 16 square Varas = 1 square Estadal = 13759 square yards; 576 square Estadals = 1 Fanegada = 16374 acres.

Capacity, liquid. 4 Cuartillas = 1 Arroba Mayor (for wine) = 3552 gallons; 1 Arroba Menor (for oil), 27652 gallons.

Capacity, dry. 12 Amuerzas = 1 Fanega = 15077 bushels.

Weight. 8 Octavos = 1 Onza = 1044 ounces; 16 Onzas = 1 Libra = 10114 pounds; 100 Libras = 1 Quintal = 101442 pounds; 10 Quintals = 1 Tonelada = 101442 pounds.

Sweden.

The French metric system became obligatory in Sweden in 1889. The following are measures according to the system formerly in use.

Length. 10 Tumer = 1 Fot = 116892 inches; 10 Fot = 1 Stang = 97411 feet; 10 Stanger = 1 Ref = 324703 yards; 360 Ref = 1 Meile = 66417 miles.

Surface. 100 square Tumer = 1 square Fot = 9489 square

foot; 1 square Ref = 2178 acre; 5.6 square Ref = 1 Tunland = 1.2198 acres.

Switzerland.

The French metric system has been generally adopted in Switzerland, with some changes of names, and of subdivisions.

Length. 10 Zoll = 1 Fuss (3 decimetres) 11.811 inches; 6 Fuss = 1 Klafter = 90.56 feet, 10 Fuss = 1 Ruthe = 98.427 feet; 1600 Ruthen = 1 Lœn = 2.9826 miles.

Surface. 100 square Fuss = 1 square Ruthe = 10.7643 square yards; 400 square Ruthen = 1 Juchart = 8694 acre; 6400 Jucharten = 1 square Stunde = 5693.52 acres.

Volume. 1000 cubic Zoll = 1 cubic Fuss = 9535 cubic foot; 1000 cubic Fuss = 1 cubic Ruthe = 35.3166 cubic yards.

Weight. 16 Unzen = 1 Pfund ($\frac{1}{2}$ kilogramme) 1.1023 pounds; 100 Pfund = 1 Centner = 110.233 pounds = 98.42 hundred-weight. The Pfund is legally divided into 500 grammes; but the people generally prefer the divisions into halves, quarters, and eighths.

Turkey

Length. 1 pike, or dirâ, or Andazé (cloth measure) = 27 inches, divided in 24 Kerâts. The Archin (land measure) = 30 inches; 1 Fersang = 3.116 miles divided into 3 Berni; Surveyor's Fik, or the Halebi = 27.9 inches; $5\frac{1}{2}$ Halebis = 1 reed.

Surface. The squares of the Kerât, the Pike, and the Reed. The Feddan is an area of land equal to as much as a yoke of oxen can plough in a day.

Capacity, dry. 900 Dirhems = 1 Rottol = 1.411 quarts; 22 Rottols = 1 Kilch = 7.762 gallons, or 97 bushels; the chief measure for grain, 100 Kilehs = 12.128 imperial quarters.

Capacity, liquid. 1 Almad = 1.152 gallons; 1 Rottol = 2.5134 pints; 100 Rottols = 1 Cantar = 31.417 gallons.

Weight. The Oke = 2.8342 pounds, 100 Rottolos = 1 Cantar = 124.704 pounds.

Malta.

Length $3\frac{1}{2}$ palmi = 1 yard; 1 Canna = $2\frac{1}{2}$ varls.

Surface. 1 Salma = 4.964 acres. Approximately, 543 square palmi = 400 square feet; 16 Salmi = 71 acres.

Volume 1 cubic Fratto = 8 cubic feet, 1 cubic Canna = 843 cubic feet.

Weight. 15 Oncie = 14 ounces; 1 Rotolo = $1\frac{1}{2}$ pounds; 44 Rotoli = 1 hundredwt; 1 Cantaro = 175 pounds; 1 Quintale = 229 pounds; 64 Cantari = 5 tons.

The weights and measures of Turkey, England, and France are all in use. The principal units are—

- 1 Cantaro = 14 sicke = 121.0 pounds (English).
- 1 Oca = 400 dramme = 2.75 pounds.
- 1 Dramma = 48.15 grains.
- 1 Pietro = 2.296 feet.
- 1 Scala = 191.4 square yards.

Candia.

The Pic = 25.11 inches; the Carga (corn) = 4.19 bushels; the Rotolo = 1.165 pounds, 100 Rotolos = 1 Cantaro = 116.5 pounds; the Okka = 2.65 pounds.

ASIA.

Burmah.

The British yard, foot, and inch are in use in Burmah; also the British measures of capacity.

The teng or cubit of 3 mark or span = 19½ inches; 4 teng = 1 lan (fathom); 7 teng = 1 ta; 1000 ta = 1 tang, nearly two English miles.

Measures of capacity depend upon the teng or basket, the value of which varies for different localities; holding from 23 pounds to 50 pounds of rice. An endeavour has been made to introduce a standard basket, containing 2218.19 cubic inches, not as yet successfully.

1 Kyat = 252 grains; 100 Kyats = 1 Piet-tha = 3.652 pounds avoirdupois.

Ceylon

The weights and measures of Ceylon are the same as those of the United Kingdom. There are also the Seer = 1.86 pints; 10 parrahs = 1 Annamam = 5.6 bushels.

China.

The Chih of 14.10 English inches is the legal standard in the tariff settled by treaty between Great Britain and China. It is the only authorised measure of length at all the ports of trade. The Fün = .141 inch, the Tsun = 1.11 inches, 10 Chih = 1 Cháng = 11.5 feet, 10 Cháng = 1 Yin = 39.17 yards. In Canton there are four different values of the chih, at Peking there are thirteen different chih.

Surface. 25 square Chih = 1 Kung = 3.36 square yards; 100 Kung = 1 Mou = 806½ square yards; 100 Mou = 1 King = 806½ acres. The Mou is the chief land measure.

Capacity. The Tou = 2½ gallons.

Weight. The Tael = $1\frac{1}{2}$ ounces ; the Katty = $1\frac{1}{2}$ pounds ; the Picul = $133\frac{1}{2}$ pounds.

Cochin China.

The Thuoë, or Cubit, 19·2 inches, is the principal unit of length ; but it varies for different places. The Li is 486 yards ; 10 Li = 1 league = 2·761 miles. 9 square Ngu = 1 square Saö = 64 square yards ; 100 square Saö = 1 square Maö = 1·32 acres. 1 Ai = ·0000006 grain ; 1 Nen = ·8594 pound ; 1 Quan = $687\frac{1}{2}$ pounds ; 1 Hao (grain) = $6\frac{2}{3}$ gallons.

Dutch East Indies—Java.

The legal weights and measures of Dutch India are those of the Netherlands. In Java, other measures are in common use. The Duim = 1·3 inches ; the Ell = 27·08 inches. The Djong of 4 Bahu = 7·015 acres. Measures of capacity are taken by definite weight : 1 Sack = 61·034 pounds : 2 Sacks = 1 Pecul = 122·068 pounds. For liquids, the Kan = ·328 gallon ; the Leager = 127·34 gallons. For weights, the Tael = 1·36 ounces ; the Pecul = 135·63 pounds.

Hong Kong.

The British weights and measures are in general use in Hong Hong. There are also the Tael = $1\frac{1}{2}$ ounces ; the Picul = 133 pounds ; the Catty = $1\frac{3}{4}$ pounds ; the Chek = $14\frac{1}{2}$ inches ; the Cheung = $12\frac{3}{16}$ feet.

India—Bengal.

Length. 1 Jow, or Jaub = $\frac{1}{4}$ inch ; 1 Guz = 1 yard ; 1 Coss = 2000 yards, or 1·1364 miles. But the Coss varies from 1 mile to 2 miles in different districts. In the Punjab it is generally 2 miles.

Surface. 4 square Hât'hs = 1 Cowrie = 1 square yard ; 1 Beegah = 1600 square yards, or ·3306 acre. For Government surveys, the following table is used :—

1 Guz	33 lineal inches.
3 Guz	1 Baus, or Rod $8\frac{1}{4}$ lineal feet.
9 Square Guz	1 Square Baus $68\frac{1}{16}$ square feet.
400 Square Baus	1 Beegah $\left\{ \begin{array}{l} 3025 \text{ square yards,} \\ \cdot 625 \text{ acre.} \end{array} \right.$

Capacity. The Seer is taken at 68 cubic inches, or 1·962 pints. But it varies. 5 Seer = 1 Palli ; 40 Seer = 1 Maund = 9·81 gallons. The Sooli = 3·065 bushels.

Weight. The Tola = 180 grains, the weight of a rupee the unit of weight ; 5 Tolas = 1 Chittâk ; 80 Tolas = 1 Seer = 2·057 pounds ; 40 Seers = 1 Maund = 82·286 pounds.

India Bombay.

The Tussoo - $1\frac{1}{2}$ inches; 16 Tussoos - 1 Hat'h - 18 inches; 24 Tussoos - 1 Guz - 27 inches. The Builder's Tussoo - 2.3625 inches in Bombay, and 1 inch in Surat.

Surface. The Katty - 9.8175 square yards; 20 Katty - 1 Pund - 196.35 square yards; 20 Pund - 1 Beegah - 8114 aca. In the Revenue Field Survey the English acre is used.

Capacity. The Seer - 36 pints, 4 Seers - 1 Pylee - 2.2401 pints, 16 Pylees - 1 Parah - 4.4802 gallons, 8 Parahs - 1 Candy - 35.8415 gallons; 25 Parahs - 112.0045 gallons. For timber measurement in Bombay Dockyards, a Covit or Candy - 12.704 cubic feet.

Weight. 1 Seer - 11.2 ounces, 1 Maund - 28 pounds, 1 Candy - 5 cwt.

According to an Act passed in 1871, the primary standard of weight is a *Seer*, equal in weight to one kilogramme - 2.2046 pounds avoirdupois. For capacity, the litre is the Standard. The divisions to be decimal.

India Madras.

The British foot and yard are in use. The Guz - 33 inches; the Baum or Fathom is about $6\frac{1}{2}$ feet. The Nall-Valli is a little less than $1\frac{1}{2}$ miles; 7 Nall Valli - 1 Kadam, or about 10 miles.

1 Span - 9 inches; 1 Cubit - 18 inches; 8000 Cubits - 1 Col - 2.27 miles.

Surface. 1 Coohe - 64 square yards; 100 Coohees - 1 Cawn - 1.3223 acres.

Capacity. 8 Olacks - 1 Puddee - 1.442 quarts; 8 Puddees - 1 Mercal - 2.885 gallons; 5 Mercals - 1 Parah - 14.425 gallons; 80 Parahs - 1 Garee - 18.033 quarters. These measures of capacity, though legal, are not commonly used. The "Customary" Puddee, in general use, has, when slightly heaped, a capacity of 1.504 quarts. The Seer measure is the most common, measuring from $66\frac{1}{2}$ to 67 cubic inches.

Weight. The Tola - 180 grains; 3 Tolas - 1 Pollum - 1.234 ounces; 8 Pollums - 1 Seer - 9.874 ounces, 5 Seers - 1 Viss - 3.086 pounds; 8 Viss - 1 Maund - 24.686 pounds; 20 Maunds - 1 Candy - 4.480 hundredwts. The Vis is usually reckoned as $3\frac{1}{4}$ pounds, the Maund as 25 pounds, the Candy as 500 pounds.

Japan

Length. The San - 1.20 inches; 10 San - 1 Shiaku - 1 foot nearly; 10 Shiaku - 1 Jô - 9 feet $11\frac{1}{2}$ inches, 60 Ken - 1 Chô - 119.4 yards, 36 Chô - 1 Ri - 2.442 miles. Cloth is measured by the Shiaku of 15 inches, divided decimally.

Surface 30 Tsubo = 1 Se = 118.615 square yards; 100 Se = 1 Cho = 2.451 acres.

Capacity. 10 Gō = 1 Shō = 3.973 gallon; 10 Shō = 1 To = 39.703 gallons; 10 To = 1 Koku = 397.03 gallons.

Weight 10 Fun = 1 Momme = 37.97 grains; 100 Momme = 1 Hiyaku me = 3.797 pound; 1000 Momme = 1 Kwam-me = 37.97 pounds; 160 Momme = 1 Kiu = 1½ pounds; 100 Kiu = 1 Hiyak-Kiu = 15.19 pounds.

Java. (*See Dutch East Indies.*)

Persia.

The unit of length is the Zer, of various lengths; the most common length is 40.95 inches. 16 Gerehs = 1 Zer. A Farsakh varies from 3.87 miles to 4½ miles in length.

Surface. The measure of surface is the Jerib - from 1000 to 1066 square Zer of 40.95 inches from 1294 to 1379 square yards.

Capacity. (Dry Goods.) 1 Sextario = 0.7236 gallon; 1 Artata = 1.809 bushels. Liquids are sold by weight.

Weight. The unit of weight is the Miskāl = 1 grain; 100 Miskāls = 1 Rotel = 1.014 pounds. 640 Miskāls = 1 Batman (of Tabreez) = 6.49 pounds; 100 Batman (of Tabreez) = 649 pounds. 1 Karwār = 649.142 pounds.

The Batman or Mau is the weight by which most articles are sold. It has very various values in different districts. Corn, straw, coal, &c., are sold by the Karwār.

Siam.

1 Niu = .9875 inch; 1 Sen = 131 feet 8 inches; 1 Yot = 9 miles, 17.15 yards, 1 foot, 8 inches. 1 Chang = 2½ pounds; 50 Chang = 123½ pounds.

Straits Settlements.

The unit measure of length is the yard, land is measured by the acre.

The Chupak or quart, of 4 paus = 8 imperial gills, 4 quartas = 1 gantang or gallon = 32 gills.

16 Pahl = 1 Kat. = 1½ pound; 100 Kat = 1 Picul = 133½ pounds; 40 Picul = 1 Koyan = 5338½ pounds.

Australasia.

In Fiji, New South Wales, New Zealand, Queensland, South Australia, Tasmania, Victoria, Western Australia, the

weights and measures are those of the United Kingdom. By the old British measures of capacity are still in use.

In land measurement, a "section" is an area equal to 80 acres.

AFRICA.

Algeria.

The French metrical system only is in use.

Arabia.

The Egyptian weights and measures are used in Arabia.

Cape Colony.

The British system of weights and measures is in use, excepting for land measure, for which the unit is the old Amsterdam Morgen, equal to 2 116/14 acres, but it is usually reckoned as 2 acres.

1 Cape foot is equal to 1 033 British foot.

Egypt

The French metric system was legally established in Egypt in 1876.

Length In the old system in general use the Pik is the unit of length. The Pik or cubit of the Nile = 20.63 inches; the indigenous Pik = 21.37 inches; the Pik of merchandise = 23.51 inches; the Pik of construction = 29.53 inches; 4.73 Piks of construction = 1 Kassaba, in surveying = 11.65 feet.

Surface 1 square Pik = 0.55 square feet; 22.41 square Piks = 1 square Kassaba = 15.07 square yards; 33.33 square Kassaba = 1 Feddan = 9342 aere.

Capacity. 1 Kelah = 3.357 gallons; 2 Kelahs = 1 Webek = 6.714 gallons; 6 Webeks = 1 Adeb = 40.404 gallons = 6.48 cubic feet. The Garban of water is $\frac{1}{15}$ cubic metre = 2.354 cubic feet.

Weight 16 Kerats = 1 Dirhem = 1.792 Drachms; 12 Okieh or 144 Dirhems = 1 Rottol = 9821 pound; 100 Rottols = 1 Kantar = 98.207 pounds. 1 Oke = 2.728 pounds.

Liberia.

The weights and measures of Liberia are mostly British.

Mauritius.

The metric system, decreed by the Government of India in 1871, came into force in Mauritius in 1878.

is equal to 1.102 pounds avoirdupois. The yard is the usual measure of length. The Colombian Vara, 80 centimetres, is also used. In liquid measure, the French litre is the legal standard.

Costa Rica.

The French metric system is in use, and its legal establishment is contemplated. The old weights and measures of Spain are in general use.

Cuba.

The old weights and measures of Spain are in general use. In engineering and carpentry, English and French measures also are in use. The French metric system is legalised, and is used in the Customs departments.

Ecuador.

The French metric system is the legal standard of this republic.

Guatemala.

The old weights and measures of Spain are in general use in Guatemala.

Haiti.

The French metric weights and measures are in use in Haiti.

Honduras.

The old weights and measures of Spain are in general use in Honduras.

British Honduras.

The British weights and measures are in use in British Honduras.

Mexico.

The weights and measures of the French metric system are legally established in Mexico. But the old Spanish measures are still in use.

Nicaragua.

The system of weights and measures in Nicaragua is that of the old weights and measures of Spain.

Paraguay.

The old weights and measures of Spain are in general use in Paraguay.

Peru.

The old weights and measures are the same as those of Bolivia and Chili. The French metric system was established in 1860, but is not yet in common use, except for the Customs tariff.

Salvador.

The weights and measures in common use in Salvador are the same as in the old Spanish system. The French metric system was introduced in 1885.

St. Domingo.

The old Spanish weights and measures are in general use. The French metric system also is in use.

United States of America.

The British Imperial system of weights and measures is employed in the United States, with the exception of the measures of capacity for dry goods and for liquids, which are the same as the old English measures. The standard U.S. gallon is the same as the old English wine gallon, or 231 cubic inches, capable of holding 8.33858 pounds of pure water of maximum density, at 39.1° F.; or $8\frac{1}{2}$ pounds at 62° F. The U.S. gallon is thus $83\frac{1}{2}$ per cent. or $\frac{125}{144}$ ths of the Imperial standard gallon.

The chain for land measurement is 100 feet long, and each foot is divided into tenths.

In City measurements the inch is the unit, divided into tenths.

In mechanical measurements, the inch is the unit, divided into 100 parts.

1 cord of wood is (4 feet \times 4 feet \times 8 feet) = 128 cubic feet.

In addition to the legalised scale of weights, the same as that of Great Britain and Ireland, there are the Quintal or Centner of 100 pounds; and the New York ton of 2,000 pounds, which is also used in the other States of the Union. These, the Centner and the New York ton, have practically superseded the British hundredweight and ton.

The French metric system of weights and measures has been legalised concurrently with the existing system.

TABLE 69. AMERICAN STANDARD WIRE-GAUGE.
(Brown and Sharpe's.)
For Sheets and Wire.

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
	Inch.		Inch.		Inch.		Inch.
4/0	·4800	8	·1280	19	·0359	30	·01003
3/0	·4096	9	·1144	20	·0320	31	·00893
2/0	·3648	10	·1019	21	·0285	32	·00795
0	·3249	11	·0907	22	·0253	33	·00708
1	·2893	12	·0808	23	·0226	34	·00603
2	·2576	13	·0720	24	·0201	35	·00561
3	·2294	14	·0641	25	·0179	36	·00500
4	·2043	15	·0571	26	·0159	37	·00445
5	·1819	16	·0508	27	·0142	38	·00397
6	·1620	17	·0453	28	·0126	39	·00353
7	·1443	18	·0403	29	·0113	40	·00314

TABLE 70. — LIQUID MEASURE (AMERICAN).
Imperial Gallons

4 gills	1 pint	
2 pints	1 quart	
4 quarts (231 cubic inches)	1 gallon	·8538
31½ gallons	1 barrel	26·250
63 gallons	1 hogshead	52·50
2 hogsheads	1 pipe, or butt	105·00
2 pipes	1 tun	210·00

TABLE 71.—DRY MEASURE (AMERICAN).

2 pints	1 quart	
4 quarts (268·8025 cubic inches)	1 gallon	·96945 Imperial gallon.
2 gallons	1 peck	1·9388 do, peck
4 pecks	1 struck bushel	·96945 do bushel

Uruguay

The French metrical system has been officially adopted; but it is not in general use. The old weights and measures are the same as those of the Argentine Republic. The weights and measures of Brazil are in general use.

Venezuela.

The French metrical system has been legally established. The system in general use is the same as that of Colombia.

West Indies.

The weights and measures are the same as those of United Kingdom.

MONEY.

Great Britain and Ireland.

		Weight Grains.
4 farthings . . .	} 1 penny . . .	145.833 bronze
2 halfpence . . .		
3 pence . . .	1 threepenny piece . . .	21.818 silver.
6 pence . . .	1 sixpence . . .	43.636 "
12 pence . . .	1 shilling . . .	87.273 "
2 shillings . . .	1 florin . . .	174.545 "
2½ shillings . . .	1 half-crown . . .	218.182 "
10 shillings . . .	1 half-sovereign . . .	61.6372 gold.
20 shillings . . .	{ 1 sovereign, or pound } sterling . . .	123.2745 "

Approximate Diameters and Weights.

	Diameter	Weight.
1 farthing . . .	.80 inch . . .	$\frac{1}{16}$ ounce.
1 halfpenny . . .	1.0 " . . .	$\frac{1}{8}$ "
1 penny . . .	1.2 " . . .	$\frac{1}{4}$ "
1 threepenny piece . . .	$\frac{5}{16}$ " . . .	$\frac{1}{10}$ "
1 sixpence . . .	$\frac{1}{2}$ " . . .	$\frac{1}{5}$ "
1 shilling . . .	$\frac{3}{4}$ " or .90 inch . . .	$\frac{1}{2}$ "
1 florin . . .	1.5 " or 1.16 " . . .	1 "
1 half-crown . . .	1.7 " . . .	1 " "
1 half-sovereign . . .	$\frac{1}{2}$ " . . .	$\frac{1}{2}$ " fully
1 sovereign . . .	$\frac{3}{4}$ " or .84 inch . . .	$\frac{1}{2}$ " fully

Composition.

Bronze . Copper, tin, and zinc.

Silver . Fine silver, 92½ per cent ; alloy, 7½ per cent.

Gold . Fine gold, 91½ per cent. , alloy, 8½ per cent.

Intrinsic Value

480 pence equal to £1 sterling

22 shillings equal to £1 sterling.

Mint price of Standard Gold, £3 17s 10½d. per ounce.

France.

Bronze.		Weight.	Diameter.	Equivalent Value. Penny.
1 centime . . .	$\frac{1}{100}$ franc . . .	1 gramme . . .	15 millimetres . . .	107
2 centimes . . .	$\frac{2}{100}$ " . . .	2 " . . .	20 " . . .	20
5 centimes . . .	$\frac{5}{100}$ " . . .	5 " . . .	25 " . . .	50
(small)				
10 centimes . . .	$\frac{10}{100}$ " . . .	10 " . . .	30 " . . .	100
(gros sou)				

				EQUIVALENT VALUE.
Silver		Weight.	Diameter	Pence.
20 centimes	$\frac{1}{5}$ franc	1 gramme	16 millimetres	2
50 centimes	$\frac{1}{2}$ "	2.5 "	18 "	4 $\frac{1}{2}$
100 centimes	1 "	5 "	23 "	9 $\frac{1}{2}$
				more exactly } 9.324
2 francs	2 "	10 "	27 "	1s. 7d.
5 francs	5 "	25 "	37 "	3s 11 $\frac{1}{2}$ d.
<i>Gold</i>				£ s. d.
5 francs	1.61290 grammes		17 millimetres	3 11 $\frac{1}{2}$
10 francs	3.22580 "		19 "	7 11 $\frac{1}{2}$
20 francs	6.45161 "	}	21 "	15 10 $\frac{1}{4}$
(napoleon)	99.56 grains			
50 francs	16.12903 grammes		28 "	1 19 8 $\frac{1}{2}$
100 francs	32.25806 "		35 "	3 19 4 $\frac{1}{2}$

The above English values of French coins are calculated at the rate of 25 francs 20 centimes to £1 sterling. The standard fineness of the gold pieces is 90 per cent., with 10 per cent. of copper.

A Monetary Convention exists between France, Belgium, Italy, Switzerland, and Spain, adopting the gold and silver coins above noted.

Germany.

The mark, of 100 pfennigs, is a silver coin of the value of 11 $\frac{1}{4}$ pence. The 10-mark gold piece is of the value of 9s. 9 $\frac{1}{2}$ d. English money. The 20-mark gold piece is equivalent to 19s. 7d. it weighs 122.92 grams. One thaler is nearly equal to 3 marks; it is equal to 3 shillings.

Other Countries in Europe

Belgium. The monetary system is the same as that of France.

Denmark.—There is a decimal system of currency. 1 krone 100 ore. 18 kronas = £1.

Greece.—The drachma = 1 franc, and 100 lepta = 1 drachma.

Italy.—The monetary system is the same as that of France. The lira, of 100 centesimi, = 1 franc.

The Netherlands. The guilder or florin, of 100 cents, = 1s. 8d. English, or 12 guilders = £1.

Portugal. The milreis, or 1000 reis, 4s. 3 $\frac{1}{2}$ d., about 4 $\frac{1}{2}$ milreis = £1; 18 $\frac{1}{2}$ reis = 1 penny. One conta (gold coin) = 10,000 reis = £2 1s. 3 $\frac{1}{2}$ d., and weighs 17.735 grammes.

Roumania. The French decimal monetary system is adopted, of which the unit is the lei = 1 franc.

Russia.—The silver rouble—100 kopecks, is the legal unit of money—3*s.* 2*054d.* English. There are three gold coins; the three-rouble, five-rouble, and ten-rouble pieces. The mark of Finland—1 franc.

Servia.—The French monetary system is adopted. The dinar=1 franc. The gold milan—20 francs.

Spain.—The peseta, of 100 centimos, =1 franc. It is equal to 4 reals, of which there are about 100 to the £1. The 25-peseta piece is 19*s.* 9½*d.* English value.

Sweden, Norway. The Swedish krona, of 100 öre, =1*s.* 14*d.* or 18 to £1. *Norway.*—The krone is of the same value as the Swedish krona.

Switzerland.—The French monetary system is legalised. The franc=10 batzen=100 rappen.

Turkey.—The lira or gold medjidieh, of 100 piastres; 18*s.* 064*d.* The piastre=2*16d.*

Malta.

1 scudo of 12 tari—1*s.* 8*d.* British money is in general circulation. The English sovereign is equal to 12 scudi; the shilling is equal to 7 tari 4 grani (20 grani = 1 taro)

Cyprus.

1 piastra, of 40 para, =1*4d.* English. Turkish, English, and French moneys also are in circulation.

Asia.

Ceylon.—The rupee of British India, with cents. The exchange value in 1887 was 1*s.* 6*d.*

China.—The haikwan tael=10 mace=100 candereens=1,000 cash. Rate of exchange in 1887, 5*s.* 0½*d.*

Dutch East Indies - Java. The guilder, or florin=100 centen=1*s.* 8*d.*

Hong Kong. The Mexican dollar—100 cents, average rate of exchange, 3*s.* 2*d.* The Chinese tael—4*s.* 5*d.*

India. The pic = ½ farthing, 3 pic = 1 pice = 1½ farthing, 4 pice = 1 anna = 1½*d.*; 16 annas = 1 rupee = 2*s.* 15 rupees = 1 gold mohur = 30*s.* 100,000 rupees is a lac of rupees; 1 millions are a crore of rupees.

Japan. The yen, or dollar, of 100 sens, nominal value, 4*s.* real value (1887), 3*s.* 4*d.*

Persia. The krân is 7½*d.* = 20 shâhis, 1 shâh = 3582*d.*

Siam.—1 tical or bat = 64 atts; rate of exchange, 2*s.* 1*d.*

Straits Settlements.—The legal tenders are, the dollar issued from Her Majesty's Mint at Hong Kong, the silver dollar

Spain, Mexico, Peru, Bolivia, the American trade dollar, and the Japanese dollar, or yen.

Australasia.—The moneys are the same as those of the United Kingdom.

Africa.

Algeria.—The French monetary system is practised.

Cape Colony. The English monetary system is practised.

Egypt. 1 piastre (tariff) of 10 lines or 40 paras = 246½ pence, 97½ pence = £1 sterling; 100 piastres = £1 Egyptian = £1 6s. 6d. 1 piastre (tariff) = 2 pence (current).

Liberia.—Chiefly British money current.

Madagascar.—The only legalised coin is the silver five-franc piece. The Italian five-lire piece is accepted.

Mauritius.—The Indian rupee is the standard coin.

Morocco.—6 floos = 1 blankee or muzzona = 09 penny.
4 blankees = 1 ounce, or okia = 38 "
10 ounces = 1 mitkal = 3-08 "

Spanish and French money are current in Morocco.

Tunis.—The piastre, of 16 karubs; average value, 6d. Spanish and French money are current in Tunis.

Zanzibar.—The Indian rupee is the coin universally current; though there is a special coinage issued under the authority of the Sultan, of which the dollar is the unit, of equal value with the American coins.

America.

Argentine Republic.—The silver dollar of 100 centesimos; average rate of exchange, 4s.

Bolivia.—The boliviano, or dollar of 100 centesimos, struck on the basis of the five-franc piece. Present value (1887), 3s. 4d.

Brazil.—The milreis of 1,000 reis. Par value, 2s. 3d.

Canada.—The dollar, of 100 cents, rate of exchange, 4s. The value of the English sovereign is by law equal to 4 dollars and 86½ cents.

Chile.—The silver peso, of 100 centavos; nominally 1 dollar, but actually coined on the basis of the five-franc piece; value, 3s. 4d.

Colombia.—The peso or dollar, of 10 reales; actual value, 3s. 4d.; nominally, 4s.

Costa Rica.—The dollar of 100 centavos; nominal value, 4s.; present value, 3s. 6d.

Ecuador.—The monetary unit is the sucre, equal to a franc piece. Average rate of exchange, 36½ pence.

Guatemala.—The dollar, or piastre, of 100 centavas; approximate value, 4s.

Haiti.—The dollar, or piastre; nominal value, 4s.; real value, 3s. 4d.

Honduras.—The dollar of 100 cents, nominal value, 4s.; real value, 3s. 4d.

Mexico.—The silver peso of 100 cents; nominal value, 4s.; real value, 3s. 1½d.

Nicaragua.—The same as for Honduras.

Paraguay.—The peso, or dollar—100 centavos; nominal value, 4s.; real value, 3s.

Peru.—The sole—100 centesimos, nominal value, 4s.; real value, 3s. 4d.

San Salvador.—The peso, or piastre, of 8 reales, approximate value, 4s. 3½d. The dollar of 100 centavos, 4s.

San Domingo.—The same as for Spain.

United States.—The dollar of 100 cents. Par value, 49·82d.; or £1 = 4·866 dollars.

Uruguay.—The peso, or dollar, of 100 centavas; approximate value, 4s. 3d., or £1 = 4·70 dollars.

Venezuela.—The venezolano of 100 centavas, approximate value, 3s. 4d. The bolivar—1 franc

SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

Density of Alloys and Amalgams.

Messrs. F. Cramm-vort and Richard Johnson investigated the conductivity of heat, tenacity, hardness, and expansion of alloys and amalgams formed with pure metals, according to the law of equivalents, and that of multiple preparations, the results of which are recorded in Table 72. It was discovered that all alloys of copper, in course of formation, make a contraction of volume, whilst all the amalgams dilate and have less than the mean density calculated in terms of the densities and proportions of the elements. Also that the maximum contraction or dilation of an alloy or an amalgam takes place generally when an equivalent of each metal is taken, except in the case of tin and zinc. These general results are attributable, no doubt, to the fact of all the alloys, except these last-named, being combinations, not mixtures. Some alloys have exceptionally great contraction or dilation. Thus, the alloy of 3 equivalents of copper to 1 of tin, has 8·954 density; calculated as a mixture, its density would only be 8·208. The amalgam of one equivalent of

with one of mercury dilates by one-tenth of the elementary volumes.

TABLE 72.—METALS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

METALS.	Specific Gravity.	Weight of	Cubic Feet per Ton.
		One Cubic Foot.	
	Water = 1.	Pounds.	Cubic Ft.
Aluminium, wrought	2.67	167	13.44
" cast	2.56	160	14.02
Antimony	6.71	418	5.35
Arsenic	5.80	361.5	6.19
Bismuth	9.90	617	3.63
Brass, cast :—	8.10	505	4.43
75 copper, 25 zinc, sheet	8.45	527	4.25
66 " 34 " yellow	8.30	518	4.32
60 " 40 " Muntz's metal }	8.20	511	4.38
Brass wire	8.55	533	4.20
Bronze :—			
84 copper, 16 tin, gun metal	8.56	534	4.19
83 " 17 " "	8.46	528	4.24
81 " 19 " "	8.46	528	4.24
79 " 21 " mill bearings	8.73	544	4.11
35 " 65 " small bells	8.06	503	4.45
21 " 79 " "	7.39	461	4.86
15 " 85 " speculum metal }	7.45	465	4.82
Calcium	1.58	98.5	22.72
Cobalt	8.50	530	4.22
Chromium	6.00	374	5.98
Copper, sheet	8.81	549	4.08
" hammered	8.92	556	4.02
" wire	8.88	554	4.04
Gold	19.24	1200	1.87
Iron, cast :—			
white	7.50	468	4.79
grey	7.20	449	4.99
hot blast	6.97	435	5.15
" 14th melting	7.53	470	4.77
mean, for ordinary calculations	7.22	450	5.00
Iron, wrought :—			
common bar, rails	7.55	471	4.74

TABLE 72.—METALS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*.)

METALS.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Feet per Ton.
	Water = 1.	Pounds.	Cubic Ft.
Iron, wrought (<i>continued</i>)			
puddled slab	7.53 to 7.60	469.5 to 474	4.77 to 4.78
various (Kirkaldy), mean	7.65	477	4.69
Yorkshire bar	7.76	484	4.65
Low Moor plates, thick	7.81	487	4.60
pure iron, by electro-deposit	8.14	508	4.41
mean, for ordinary calculations	7.70	480	4.66
Lead, milled sheet	11.42	712	3.14
" wire	11.28	704	3.18
Lithium . . . . .	.59	37	6.08
Magnesium	1.74	108.5	20.63
Manganese	8.00	499	4.48
Mercury	13.60	849	2.64
Nickel, hammered	8.67	541	4.14
" cast	8.28	516	4.34
Platinum	21.52	1342	1.67
Potassium . . . . .	.86	53.6	41.65
Silver	10.50	655	3.42
Sodium . . . . .	.97	60.5	37.01
Steel:—			
blistered	7.82	488	4.59
crucible	7.84	489	4.58
cast	7.85	489.5	4.57
Bessemer	7.85	489.6	4.57
for ordinary calculations	7.86	490	4.57
Tin	7.41	462	4.84
Zinc, sheet	7.20	440	4.99
" cast	6.86	428	5.22

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS.

(F. Grace-Calvert and R. Johnson.)

I. ALLOYS OF GREATER THAN CALCULATED MEAN DENSITY: WITH CONTRACTION.

Alloy.	Proportions per cent. by Weight.	Density ob- tained.	Density calcu- lated.	Diffe- rence.
1. <i>Copper and Tin</i> (bronze)				
Cu Sn ⁵	C 9.73	7.517	7.431	.086
	T 90.27			
Cu Sn ⁶	C 11.86	7.558	7.462	.096
	T 88.14			
Cu Sn ⁸	C 15.21	7.606	7.514	.092
	T 84.79			
Cu Sn ¹⁰	C 21.21	7.738	7.580	.158
	T 78.79			
Cu Sn	C 34.98	7.992	7.805	.187
	T 65.02			
Sn Cu ³	T 51.83	8.533	8.059	.474
	C 48.17			
Sn Cu ⁴	T 38.21	8.954	8.208	.746
	C 61.79			
Sn Cu ⁶	T 31.73	8.948	8.306	.642
	C 68.27			
Sn Cu ⁸	T 27.10	8.965	8.374	.591
	C 72.90			
Sn Cu ¹⁰	T 15.68	8.832	8.545	.287
	C 84.32			
Sn Cu ¹⁵	T 11.03	8.825	8.615	.210
	C 88.97			
Sn Cu ²⁰	T 8.51	8.793	8.634	.159
	C 91.49			
Sn Cu ²⁵	T 6.83	8.820	8.677	.143
	C 93.17			
2. <i>Copper and Zinc</i> (brass)				
Zn Cu ⁵	C 82.95	8.673	8.453	.220
	Z 17.05			
Zn Cu ⁶	C 79.56	8.650	8.387	.263
	Z 20.44			
Zn Cu ⁸	C 74.48	8.576	8.290	.286
	Z 25.52			

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

ALLOY.	Proportions per cent. by Weight	Density ob- tained	Density cal- culated	Diffe- rence.
2. <i>Copper and Zinc</i> (brass, (continued).)				
Zn Cu ²	C 66.96 Z 33.94	8.488	8.129	.359
Zn Cu	C 49.32 Z 50.58	7.808	8.319	.511
Cu Zn ³	C 32.74 Z 67.26	7.859	7.489	.370
Cu Zn ⁴	C 24.64 Z 75.36	7.736	7.334	.401
Cu Zn ⁵	C 19.57 Z 80.43	7.445	7.237	.208
Cu Zn ⁶	C 16.80 Z 83.70	7.442	7.174	.268
3. <i>Copper and Bismuth</i>				
Cu Bi		9.634	9.566	.068
4. <i>Copper and Antimony</i> .				
Cu Sb		7.990	7.386	.604
5. <i>Tin and Zinc</i> .				
Zn Sn ⁷	Z 21.65 T 78.35	7.274	7.193	.081
Zn Sn	Z 35.60 T 64.40	7.262	7.134	.128
Sn Zn ⁸	T 47.49 Z 52.51	7.188	7.060	.128
Sn Zn ⁹	T 37.57 Z 62.43	7.180	7.021	.159
Sn Zn ¹⁰	T 31.14 Z 68.86	7.155	6.993	.162
Sn Zn ¹¹	T 26.57 Z 73.43	7.140	6.974	.161
Sn Zn ¹²	T 15.32 Z 84.68	7.135	6.927	.208

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

1. ALLOYS AND AMALGAMS OF LESS THAN CALCULATED
MEAN DENSITY WITH DILATATION.

ALLOY.	Proportions per cent. by Weight.	Density ob- tained.	Density calcu- lated.	Diffe- rence.
<i>1. Mercury and Tin.</i>				
Hg Sn	(M 62.97 T 37.03)	10.255	11.259	1.004
Hg Sn ²	(M 45.88 T 54.12)	9.314	10.180	.866
Hg Sn ³	(M 36.18 T 63.82)	8.805	9.568	.763
Hg Sn ⁴	(M 29.84 T 70.16)	8.510	9.168	.658
Hg Sn ⁵	(M 25.38 T 74.62)	8.312	8.885	.573
Hg Sn ⁶	(M 22.08 T 77.92)	8.151	8.678	.527
<i>Mercury and Bismuth.</i>				
Hg Bi	(M 48.44 B 51.56)	11.208	11.638	.430
Hg Bi ²	(M 31.82 B 68.18)	10.693	11.007	.314
Hg Bi ³	(M 23.86 B 76.14)	10.474	10.704	.230
Hg Bi ⁴	(M 19.03 B 80.97)	10.350	10.522	.172
Hg Bi ⁵	(M 15.82 B 84.18)	10.240	10.410	.170
<i>Mercury and Zinc</i>		11.304	11.944	.640
<i>1. Antimony and Bismuth.</i>				
Bi Sb ⁴	(B 24.81 A 75.19)	7.271	7.470	.201
Bi Sb ⁵	(B 29.20 A 70.80)	7.370	7.606	.235
Bi Sb ⁶	(B 35.48 A 64.52)	7.561	7.801	.240
Bi Sb ⁷	(B 45.21 A 54.79)	7.829	8.102	.273
Bi Sb	(B 62.26 A 37.74)	8.364	8.630	.266

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

ALLOY.	Proportions per cent. by Weight	Density ob- tained	Density calcu- lated	Diffe- rence.
2. <i>Copper and Zinc</i> (brass) (continued.)				
Zn Cu ²	C 66.06 Z 33.94	8.488	8.129	.359
Zn Cu	C 49.32 Z 50.68	7.808	8.319	.511
Cu Zn ³	C 32.74 Z 67.26	7.859	7.489	.370
Cu Zn ³	C 24.64 Z 75.36	7.736	7.334	.401
Cu Zn ⁴	C 19.57 Z 80.43	7.445	7.237	.208
Cu Zn ⁵	C 15.30 Z 84.70	7.442	7.174	.268
3. <i>Copper and Bismuth</i> Cu Bi				
		9.634	9.566	.068
4. <i>Copper and Antimony</i> Cu Sb				
		7.990	7.386	.604
5. <i>Tin and Zinc</i> .				
Zn Sn ²	Z 21.65 T 78.35	7.274	7.193	.081
Zn Sn	Z 35.60 T 64.40	7.262	7.134	.128
Sn Zn ²	T 47.49 Z 52.51	7.188	7.060	.128
Sn Zn ³	T 37.57 Z 62.43	7.180	7.021	.159
Sn Zn ⁴	T 31.14 Z 68.86	7.155	6.993	.162
Sn Zn ⁵	T 26.57 Z 73.43	7.140	6.974	.161
Sn Zn ¹⁰	T 15.32 Z 84.68	7.135	6.927	.208

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

I. ALLOYS AND AMALGAMS OF LESS THAN CALCULATED
MEAN DENSITY, WITH EXPLANATION.

ALLOY.	MEAN DENSITY CALCULATED.	MEAN DENSITY OBSERVED.	EXPLANATION.
<i>Mercury and Tin.</i>			
Hg Sn . . .	13.50	13.40	Mercury
Hg Sn ² . . .	13.50	13.40	Mercury
Hg Sn ³ . . .	13.50	13.40	Mercury
Hg Sn ⁴ . . .	13.50	13.40	Mercury
Hg Sn ⁵ . . .	13.50	13.40	Mercury
Hg Sn ⁶ . . .	13.50	13.40	Mercury
<i>Mercury and Bismuth.</i>			
Hg Bi	13.50	13.40	Mercury
Hg Bi ²	13.50	13.40	Mercury
Hg Bi ³	13.50	13.40	Mercury
Hg Bi ⁴	13.50	13.40	Mercury
Hg Bi ⁵	13.50	13.40	Mercury
<i>Mercury and Zinc</i>			
<i>Aluminum and Bismuth</i>			
Al Bi	13.50	13.40	Aluminum
Al Bi ²	13.50	13.40	Aluminum
Al Bi ³	13.50	13.40	Aluminum
Al Bi ⁴	13.50	13.40	Aluminum
Al Bi ⁵	13.50	13.40	Aluminum

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

ALLOY	Proportions per cent. by Weight.	Density ob- tained	Density calc. lated.	Difference
9. <i>Antimony and Bismuth</i> (continued).				
Sb Bi ²	A 23.26	8.859	9.077	.218
	B 76.74			
Sb Bi ³	A 16.81	9.095	9.277	.182
	B 83.19			
Sb Bi ⁴	A 13.17	9.276	9.391	.119
	B 86.83			
Sb Bi ⁵	A 10.82	9.369	9.464	.095
	B 89.18			
10. <i>Bismuth and Zinc.</i>				
Bi Zn		9.046	9.132	.086
11. <i>Tin and Lead.</i>				
Pb Sn ¹	L 26.03	8.023	8.367	.254
	T 73.97			
Pb Sn ²	L 30.57	8.196	8.548	.352
	T 69.43			
Pb Sn ³	L 36.99	8.418	8.823	.405
	T 63.01			
Pb Sn ⁴	L 46.82	8.774	9.232	.458
	T 53.18			
Pb Sn	L 63.78	9.458	9.938	.480
	T 36.22			
Sn Pb ¹	T 22.11	10.105	10.525	.420
	L 77.89			
Sn Pb ²	T 15.91	10.421	10.783	.362
	L 84.09			
Sn Pb ³	T 12.43	10.587	10.927	.340
	L 87.57			
Sn Pb ⁴	T 10.20	10.751	11.017	.266
	L 89.80			
12. <i>Lead and Antimony.</i>				
Sb Pb ¹	A 11.08	10.556	10.919	.363
	L 88.92			
Sb Pb ²	A 13.48	10.387	10.805	.418
	L 86.52			
Sb Pb ³	A 17.20	10.136	10.629	.493
	L 82.80			

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

ALLOY.	Proportions per cent. by Weight.	Density ob- tained.	Density calcu- lated.	Diffe- rence.
2. <i>Lead and Antimony</i> (continued).				
Sb Pb ²	{ A 23.68 } L 76.32 }	9.723	10.321	.598
Sb Pb	{ A 38.39 } L 61.61 }	8.953	9.624	.671
Pb Sb ²	L 44.53 } A 55.47 }	8.330	8.959	.629
Pb Sb ³	L 34.86 } A 65.14 }	7.830	8.355	.525
Pb Sb ⁴	L 28.64 } A 71.36 }	7.525	8.059	.534
Pb Sb ⁵	L 24.31 } A 75.69 }	7.432	7.854	.422

TABLE 74.—STONES: SPECIFIC GRAVITY, WEIGHT
AND VOLUME.

STONES.	Specific Gravity.	Weight of one Cubic Foot.	Cubic Feet per Ton.
	Water=1.	Pounds.	Cubic Ft.
Alabaster, calcareous	2.76	172.1	13.0
" gypseous	2.31	144.0	15.6
Barytes	4.45	277.5	8.07
Basalt	2.45 to } 3.00	152.8 to } 187.1	14.7 to } 12.0
Chalk, air-dried	2.50	155	14.5
Diamond	3.50	...	...
Flint	2.63	164	13.7
Felspar	2.60	162.1	13.8
Gneiss	2.69	168	13.3
Granite	25.0 to } 27.4	156 to } 171	14.4 to } 13.1
Graphite	2.20	137.2	16.3
Isler	2.72	169.7	13.2
Lias	2.25 to } 2.45	140.3 to } 152.8	16.0 to } 14.7
Limestone	1.86 to } 2.53	116 to } 158	19.3 to } 14.2

TABLE 77. MINERAL SUBSTANCES, VARIOUS SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*).

SUBSTANCE.	Specific Gravity	Weight of One Cubic Foot.	Cubic Feet per Ton.
	Water = 1	Pounds.	Cubic Feet.
Mud :—			
Dry, close	1.28 to 1.93	80 to 110	28.0 to 20.0
Wet, moderately pressed	1.93 to 2.09	110 to 130	20.0 to 17.0
Wet, fluid	1.67 to 1.92	104 to 120	21.6 to 18.0
Phosphorus	1.77	110.4	20.0
Plaster	1.57	98	22.0
Portland cement	1.25 to 1.51	78 to 94	28.7 to 23.7
Potash	2.10	131	17.0
Sand	1.44 to 1.87	90 to 117	24.7 to 19.0
„ saturated with water	1.89 to 2.07	118 to 129	19.0 to 17.0
Salt, common	1.92	119.7	18.0
„ rock	2.10 to 2.26	131 to 140.7	17.0 to 15.0
Salt bar	2.00	124.7	18.0
Talc	2.60	164.7	13.0

TABLE 77a. FIELDS IN FRANCE.

	Weight of One Cubic Foot.	Specific Gravity.
	Pounds.	Water = 1.
Peat, compact	14.5	2.0
Anthracite	83.0 to 91.0	1.34 to 1.40
Rich coal with a long flame	81.0 to 84.8	1.28 to 1.30
Lean coal with a long flame	84.8	1.30
Lean coal and charcoal	81.3	1.30
Sooty coal	79.8 to 81.1	1.28 to 1.30
Lignite	77.0 to 84.2	1.25 to 1.30
„ bituminous	73.8 to 74.8	1.16 to 1.17
„ imperfect	81.0	1.30
Bitumen, red	72.0	1.16
„ black	81.0	1.30
„ brown	81.0	1.30
„ white	86.7	1.30

TABLE 78.—WEIGHT AND VOLUME IN BULK OF VARIOUS SOLIDS.
(Tredgold.)

SUBSTANCE.	Weight of One Cubic Foot in bulk.	Volume of One Ton in bulk.
	Pounds.	Cubic Feet.
Lead, cast in pigs	567	4
Iron, cast in pigs	360	6.25
Limestone or Marble, in blocks	172	13
Granite, Aberdeen, in blocks	166	13.5
" Cornish, "	164	14
Sandstone, in blocks	141	16
Portland Stone, in blocks	132	17
Potter's Clay	130	17
Loam or Strong Soil	126	18
Bath Stone, in blocks	123.5	18
Gravel	109	21
Sand	95	23.5
Bricks, Common Stock, dry	93	24
Culm	63	36
Water, River	62.5	36
Splint Coal	57	39.5
Oak, Seasoned	52	43
Coal (Newcastle) caking	50	45
Wheat	48	47
Barley	38	59
Red Fir	38	59
Hay, compact, old	8	280

TABLE 79.—MEASURES OF ORES, EARTH, &c.
(Rand Drill Company.)

	Weight.
14.5 Cubic Feet of ordinary Gold or Silver Ore, in mine	1 ton
22 " of Broken Quartz	1 "
20 " Gravel, in bank	1 "
30 " Gravel, when dry	1 "
28 " Sand	1 "
20 " Earth, in bank	1 "
30 " " " when dry	1 "
19 " Clay	1 "
45 " Bituminous Coal, heaped	1 "
42 " Anthracite	1 "
143 " Charcoal	1 "
71 " Coke	1 "

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

ALLOY.	Proportions per cent. by Weight	Density ob- tained	Density calcu- lated.	Dif- ference
9. <i>Antimony and Bismuth.</i> (continued).				
Sb Bi ²	A 23.26 B 76.74	8.859	9.077	.218
Sb Bi ³	A 16.81 B 83.19	9.095	9.277	.182
Sb Bi ⁴	A 13.17 B 86.83	9.276	9.391	.115
Sb Bi ⁵	A 10.82 B 89.18	9.369	9.464	.095
10. <i>Bismuth and Zinc.</i> Bi Zn				
		9.046	9.132	.086
11. <i>Tin and Lead.</i>				
Pb Sn ¹	L 26.03 T 73.97	8.093	8.367	.254
Pb Sn ²	L 30.57 T 69.43	8.196	8.548	.352
Pb Sn ³	L 36.99 T 63.01	8.418	8.823	.405
Pb Sn ⁴	L 46.82 T 53.18	8.774	9.232	.458
Pb Sn	L 63.78 T 36.22	9.458	9.938	.480
Sn Pb ²	T 22.11 L 77.89	10.105	10.525	.420
Sn Pb ³	T 15.91 L 84.09	10.421	10.783	.362
Sn Pb ⁴	T 12.43 L 87.57	10.587	10.927	.340
Sn Pb ⁵	T 10.20 L 89.80	10.751	11.017	.266
12. <i>Lead and Antimony.</i>				
Sb PL ¹	A 11.08 L 88.92	10.556	10.919	.363
Sb Pb ²	A 13.48 L 86.52	10.387	10.805	.418
Sb PL ³	A 17.20 L 82.80	10.136	10.629	.493

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS
(continued).

ALLOY.	Proportions per cent. by Weight.	Density ob- tained.	Density calcu- lated.	Diffe- rence.
12. <i>Lead and Antimony</i> (continued).				
Sb Pb ²	{ A 23·68 L 76·32 }	9·723	10·321	·598
Sb Pb	{ A 38·39 L 61·61 }	8·953	9·624	·671
Pb Sb ²	{ L 44·53 A 55·47 }	8·330	8·959	·629
Pb Sb ³	{ L 34·86 A 65·14 }	7·830	8·355	·525
Pb Sb ⁴	{ L 28·64 A 71·36 }	7·525	8·059	·534
Pb Sb ⁵	{ L 24·31 A 75·69 }	7·432	7·854	·422

TABLE 74.—STONES: SPECIFIC GRAVITY, WEIGHT
AND VOLUME.

STONES.	Specific Gravity.	Weight of one Cubic Foot.	Cubic Feet per Ton.
	Water=1.	Pounds.	Cubic Ft.
Alabaster, calcareous	2·76	172·1	13·0
„ gypseous	2·31	144·0	15·6
Barytes	4·45	277·5	8·07
Basalt	2·45 to 3·00	152·8 to 187·1	14·7 to 12·0
Chalk, air-dried	2·50	155	14·5
Diamond	3·50	...	...
Flint	2·63	164	13·7
Felspar	2·60	162·1	13·8
Gneiss	2·69	168	13·3
Granite	25·0 to 27·4	156 to 171	14·4 to 13·1
Graphite	2·20	137·2	16·3
Jasper	2·72	169·7	13·2
Lias	2·25 to 2·45	140·3 to 152·8	16·0 to 14·7
Limestone	1·86 to 2·53	116 to 158	19·3 to 14·2

TABLE 74.—STONES SPECIFIC GRAVITY, WEIGHT AND VOLUME (*continued*).

Stones.	Specific Gravity	Weight of one Cubic Foot.	Cubic Feet per Ton.
	Water 1	Pounds.	Cubic Feet.
Marble			
African	2.80	174.6	12.8
British	2.71	169.0	13.3
Carrara	2.72	169.6	13.2
Egyptian green	2.67	166.5	13.5
Florentine	2.52	157.1	14.3
French	2.65	165.2	13.6
Mica	2.93	183	12.2
Oolitic stones	1.89 to 2.60	118 to 162	19.0 to 13.8
Ores .			
Specular or red iron ore	5.21	327.4	6.84
Magnetic iron ore	5.09	317.6	7.05
Brown iron ore	3.42	244.6	9.16
Spathic iron ore	3.83	238.8	9.36
Clydesdale iron ore	3.05	190.5	11.76
Potter's stone	2.80	174.6	12.8
Quartz	2.61 to 2.71	162.8 to 169	13.8 to 13.3
.. broken up and heaped	1.96	122	20
.. quarry debris	1.47	91.4	24.5
Rock crystal	2.65	165.4	13.6
Sandstone	2.04 to 2.70	127 to 168	17.6 to 13.3
Serpentine	2.81	175.2	12.8
Slate	2.60 to 2.85	162.1 to 177.7	13.8 to 12.6
Talc, steatite	2.70	168.4	13.3
Trap, touchstone	2.72	169.6	13.2

ARTIFICIAL STONES.

Appenite — Ransom's silicious stone (silica, soda, water)	1.60	99.7	22.5
Concrete .			
Portland cement 1, and shingle 10	2.23	139	16.1
Portland cement, rubble, and sand	2.17 to 2.25	135 to 140	16.6 to 13.5

TABLE 74.—STONES: ARTIFICIAL STONES (*continued*).

Concrete :—(<i>continued</i>).			
Portland cement 1, and sand 2	2.04	127	17.6
Roman cement 1, and sand 2	1.92	120	18.7
Victoria stone (crushed granite, Portland cement, silica)	2.31	144	15.6

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES.
(Gwilt.)

STONES.	Weight of One Cubic Foot.
1. GRANITES.	
	Pounds.
Stirling Hill, Stirling	165.9
High Rock, Breadalbane	166.0
Black Hill, Stirling	166.6
Dalkey, Dublin	169.6
Bars, Breadalbane	169.7
Haytor, Devonshire	165.2
Blue Penmaenmaur, Carnarvonshire	160.1
Aberdeen Grey, Aberdeenshire	166.5
„ Red	165.3
Cornish Grey, Cornwall	166.7
„ Red	164.0
Average	166.0
2. LIMESTONES.	
Beer, Devonshire	131.7
Chilmark, Wiltshire	153.4
Hopton Wood, Derbyshire	158.4
Sea Combe, Dorsetshire	151.0
Sutton, Glamorganshire	136.0
Tottenham, Bedfordshire	116.5
Average	141.2
3. MAGNESIAN LIMESTONES.	
Bolsover, Denbigh	151.7
Brantsworth, Yorkshire	133.6
Cadeby	126.6

TABLE 75 — WEIGHT AND COMPOSITION OF BUILDING STONES (continued)

STONES	Weight of One Cubic Foot
3 MAGNESIAN LIMESTONES (continued)	
Huddlestone	137.8
Rochester Abbey	139.1
Smawes	127.5
Average	130.0
4 OOLITIC STONES	
Ancaster, Lincolnshire	139.2
Barnack Mill, Northamptonshire	156.7
Bath Lodge Hill, Somersetshire	116.0
Bath Baynton	123.3
Bath (Drew's Quarry)	122.6
Cranmore, Wiltshire	134.2
Haydon, Lincolnshire	138.5
Ketton, Rutlandshire	128.3
Portland	120.4 to 147.0
Taynton, Oxon.	137.9
Wass, Yorkshire	soft, 141.7 hard, 162.1
Windrush, Gloucestershire	soft, 118.5 hard, 135.6
Average	133.5
5 SANDSTONES	
Abercrombie, Monmouth	167.9
Barbadoes, Tintern, Monmouth	140.7
Binnie, Linlithgowshire	140.1
Bolton's Quarry, Yorkshire	126.7
Bramley Fall	142.2
Calverley, Kent	138.1
Craigleith, Edinburgh	147.9
Craw Bank, Linlithgowshire	129.1
Duffield, Derbyshire	132.9
Duke's Quarries, Derbyshire	114.5
Elland Edge, Yorkshire	158.2
Gaithley Moor	135.8
Gatton, Surrey	103.1
Glamis, Forfarshire	161.1
Heddon, Northumberland	130.7
Hellington, Staffordshire	133.1
Humble, Linlithgow	white, 133.1 grey, 133.1

LE 75,—WEIGHT AND COMPOSITION OF BUILDING STONES (continued.)

STONES.	Weight of One Cubic Foot.
5. SANDSTONES (<i>continued</i>).	
annet, Perthshire	131·7
ochy, Ross-shire	160·6
efield, Perthshire	160·0
Spring, Yorkshire	151·1
er, Durham	134·3
Dykes, Forfarshire	162·5
ate, Yorkshire	158·0
cliff, Derbyshire	148·2
on, Durham	142·5
by Company's, Aislaby, Yorkshire	126·7
„ Egton „	127·0
„ Sneaton „	134·8
„ Newton Dale „	131·7
Average	140·5

6. MARBLES.

Kilkenny	171·4
Hebrides	172·3
ra (Statuary), Tuscany	168·6
Ravaccione	169·1
pen, Devonshire	163·4
Average	169·0

General Composition of the above Stones.

ROCKS.	Carbonate of Lime.	Mag- nesia.	Silica.	Iron, Alumina, Water, and Loss.	Total.
	Per cent.	Pr. cent.	Pr. cent.	Per cent.	
stones . . .	81.0	4.2	5	9.8	100.0
Magnesian	54.6	40.6	2	2.8	100.0
ic Stones . .	94.0	2.7	...	3.3	100.0
stones . . .	1.1	...	95.5	3.4	100.0
les . . .	lime				
	56.5				
	carbonic acid	...	...	water . . .	100.0
	43.0				

TABLE 77. MINERAL SUBSTANCES, VARIOUS SPECIES.
GRAVITY, WEIGHT, AND VOLUME (*continued*).

SUBSTANCE	Specific Gravity	Weight of One Cubic Foot	Cubic Feet per Ton
	Water = 1	Pounds.	Cubic Feet
Mud :—			
Dry, close	1.28 to 1.93	80 to 110	28.0 to 20.4
Wet, moderately pressed	1.93 to 2.39	110 to 130	20.4 to 17.2
Wet, fluid	1.67 to 1.92	104 to 120	21.5 to 18.7
Phosphorus	1.77	110.1	20.5
Plaster	1.57	98	22.5
Portland cement	1.25 to 1.51	78 to 94	28.7 to 23.8
Potash	2.10	131	17.1
Sand	1.44 to 1.87	90 to 117	24.9 to 19.1
" saturated with water	1.89 to 2.07	118 to 129	19.1 to 17.4
Salt, common	1.92	119.7	18.7
" rock	2.10 to 2.26	131 to 140.7	17.1 to 15.6
Sulphur	2.00	124.7	18.0
Tiles	2.00	124.7	18.0

TABLE 77a.—FUELS IN FRANCE

	Weight of One Cubic Foot	Specific Gravity
	Pounds	Water = 1
Peat, compact	14.1	2.32
Anthracite	82.5 to 90.0	1.34 to 1.40
Rich coal with a long flame	72.5 to 84.8	1.18 to 1.30
Dry coal with a long flame	84.8	1.30
Rich and hard coal	84.8	1.32
Semibituminous	72.5 to 84.1	1.18 to 1.30
Light	72.5 to 84.1	1.18 to 1.30
" bituminous in perfect	81.7	1.31
Bitumen, red	72.5	1.18
" black	84.1	1.30
" brown	84.1	1.30
Asphalt	107.7	1.74

TABLE 78.—WEIGHT AND VOLUME IN BULK OF VARIOUS SOLIDS.
(Tredgold.)

SUBSTANCE.	Weight of One Cubic Foot in bulk.	Volume of One Ton in bulk.
	Pounds.	Cubic Feet.
Lead, cast in pigs	567	4
Iron, cast in pigs	360	6.25
Limestone or Marble, in blocks	172	13
Granite, Aberdeen, in blocks	166	13.5
„ Cornish, „	164	14
Sandstone, in blocks	141	16
Portland Stone, in blocks	132	17
Potter's Clay	130	17
Loam or Strong Soil	126	18
Bath Stone, in blocks	123.5	18
Gravel.	109	21
Sand	95	23.5
Bricks, Common Stock, dry	98	24
Culm	63	36
Water, River	62.5	36
Splint Coal	57	39.5
Oak, Seasoned	52	43
Coal (Newcastle) caking	50	45
Wheat	48	47
Barley	38	59
Red Fir	38	59
Hay, compact, old	8	280

TABLE 79.—MEASURES OF ORES, EARTH, &C.
(Rand Drill Company.)

	Weight.
14.5 Cubic Feet of ordinary Gold or Silver Ore, in mine	1 ton
22 „ of Broken Quartz	1 „
20 „ Gravel, in bank	1 „
30 „ Gravel, when dry	1 „
28 „ Sand	1 „
20 „ Earth, in bank	1 „
30 „ „ when dry	1 „
19 „ Clay	1 „
45 „ Bituminous Coal, heaped	1 „
42 „ Anthracite	1 „
123 „ Charcoal	1 „
71 „ Coke	1 „

200 SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

		Weight
1	Cubic Foot Anthracite, heaped	50 lb. to 55 lb.
1	" Bituminous Coal "	45 lb. to 55 lb.
1	" Cumberland Coal "	53 lb.
1	" Channel Coal "	50½ lb.
1	" Hardwood Charcoal "	18½ lb.
1	" Pine Charcoal "	18 lb.

	Weight.	Equivalent in Feet to
1 Cord of Wood, 4 feet x 4 feet x 8 feet		128 cubic feet
1 Cord of air-dried Hickory or Hard Maple	4,500 lb.	2,000 lb. cord
1 " " White Oak	3,850	1,715 "
1 " " Beech, Red Oak or Black Oak	3,250 "	1,450 "
1 " " Poplar (white wood), Chestnut, or Elm	2,350 "	1,050 "
1 " " Average Pine	2,000 "	925 "

TABLE NO. — FUELS SPECIFIC GRAVITY, WEIGHT, AND BULK.

FUELS.	Specific Gravity.	Weight of one Cubic Foot		Volume of One Ton heaped
		Solids	Heaped	
	Water 1	Lbs.	Lbs.	Cub. Ft.
COALS.				
Anthracite	1.37	82.4	58.3	38.4
" American	1.30 to 1.84	83.5	54.0	...
Welsh	1.32	82.3	53.1	42.7
Newcastle	1.25	78.3	49.8	47.3
Derbyshire and Yorkshire	1.29	79.6	45.9	47.4
Lancashire	1.27	79.1	49.7	45.2
Scotch	1.26	78.6	50.0	42.0
Irish Shevardagh anthracite, etc.	1.59	100.6	62.8	35.7
Bituminous coal American	1.35	84.0	50.0	...
Belgian (Scotland)	1.18			...
COKE.				
Coke generally	..	40 to 50	30.0	70 to 80
Tanfield	.74	46	30.0	74.5

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
COKE (<i>continued</i>).				
Gas coke . . . . .	...	...	23·8 to 28·6	...
American . . . . .	...	...	32·1	69·8
Seraing (France) . . . . .	...	...	31·0	72·0
Graphite	2·33	145·3	...	...
LIGNITE AND ASPHALTE.				
Perfect lignite	1·29	...	...	...
Imperfect lignite	1·15	...	...	...
Bituminous lignite	1·18	...	...	...
Asphalte	1·06	...	...	...
WOOD.—See Table 81.				
WOOD CHARCOAL.				
<i>As made, heaped.</i>				
	Heaped.			
Oak and beech	·24 to ·25	...	15 to 15·6	...
Birch	·22 to ·23	...	13·7 to 14·3	...
Pine	·20 to ·21	...	12·5 to 13·1	...
Average	·225	...	14	...
<i>In small pieces, heaped.</i>				
Walnut	·63	...	39·3	...
Ash	·53	...	34·3	...
Beech	·52	...	32·5	...
Yoke-Elm	·46	...	28·7	...
Appleton	·46	...	28·7	...
White oak	·42	...	26·2	...
Cherry tree	·41	...	25·6	...
Birch	·36	...	22·5	...
Elm	·36	...	22·5	...
Yellow pine	·33	...	20·6	...
Chestnut tree	·28	...	17·5	...
Poplar	·25	...	15·6	...
Cedar	·24	...	15·0	...
Average	·405	...	25·3	...

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
<i>As Powder.</i>				
Willow	1.55	...	96.7	...
Oak	1.53	...	95.4	...
Alder	1.49	...	92.9	...
Lime tree	1.46	...	91.0	...
Poplar	1.45	...	90.4	...
Average	1.50	...	98.5	...
Gunpowder, loose . . . . .	.90	...	...	...
" shaken	1.00	...	...	...
" solid	1.55 to 1.80	...	...	...
<i>Irish Peat.</i>				
Very light, spongy, surface peat . . . . .	.22 to .34	13.7 to 21.0	...	...
Light surface peat . . . . .	.34 to .41	20.9 to 25.3	...	...
Rather dense . . . . .	.48 to .67	29.7 to 41.7	...	...
Very dense, dark brown . . . . .	.65 to .71	40.5 to 44.5	...	...
Very dense, blackish brown, compact . . . . .	.72 to .98	45.1 to 61.3	...	...
Exceedingly dense, jet black . . . . .	.73 to .99	53.2 to 61.8	...	...
Exceedingly dense, dark blackish brown	1.05	66.0	...	...
Upper moss . . . . .	...	...	6.06 to 8.81	369.6 to 254.2
Brown . . . . .	...	...	15.13	147.0
Compact black . . . . .	...	...	17.06	131.3
Densest black . . . . .	...	...	22.54	99.4
Condensed peat	1.0 to 1.3	62.5 to 81.1	43.7 to 56.8	51.2 to 40.0

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT.

WOOD.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Acacia	.82	51.1
„ with 20 per cent. moisture	.72	44.9
Alder tree	.56	34.9
„ with 20 per cent. moisture	.60	37.4
Ash	.84	52.4
„ with 20 per cent. moisture	.70	43.7
Aspen tree	.60	37.4
Apple tree	.73	45.5
Bamboo	.31 to .40	19.5 to 24.9
Beech	.75 to .85	46.8 to 50.3
„ with 20 per cent. moisture	.82	51.1
„ cut one year	.66	41.2
Birch	.72 to .74	44.9 to 46.1
Boxwood	1.04	64.8
Cedar of Lebanon	.49 to .57	30.6 to 35.5
Cork	.24	15.0
Cypress, cut one year	.66	41.2
Ebony	1.13	70.5
„ Green	1.21	75.5
„ Black	1.19	74.2
Elder path	.076	4.74
Elm	.55	34.3
„ Green	.76	47.5
„ with 20 per cent. moisture	.72	44.9
Fir, Norway Pine	.74	46.1
„ Red Pine	.48 to .70	29.9 to 43.7
„ Spruce	.48 to .70	29.9 to 43.7
„ Larch	.50 to .64	31.2 to 39.9
„ White Pine, English	.55	34.3
„ „ Scotch	.53	34.3
„ „ with 20 per cent. moisture	.49	30.6
„ Yellow Pine	.66	41.2
„ „ American	.46	28.7
Hawthorn	.91	56.7
Holly	.76	47.5
Hornbeam	.76	47.5
Laburnum	.92	57.4
Lance Wood	.67 to 1.01	41.8 to 63.6
Lignum-Vita	.65 to 1.33	40.5 to 82.9

TABLE 81.—WOODS : SPECIFIC GRAVITY AND WEIGHT
(continued).

WOOD.	Specific Gravity.	Weight of One Cubic Foot.
	Water=1.	Pounds.
Mahogany, Spanish	·85	53·0
„ St. Domingo	·75	46·8
„ Cuba	·56	34·9
„ Honduras	·56	34·9
Maple	·65	40·5
„ 20 per cent. moisture	·67	41·8
Mulberry	·89	55·5
Oak, Heart of	1·17	73·0
„ English	·93	58·0
„ European	·69 to ·99	43·0 to 61·7
„ American Red	·87	54·2
Olive tree	·68	42·4
Orange tree	·71	44·8
Pear tree	·73	45·3
Plane tree	·65	40·5
Plum tree	·87	54·2
Pomegranate	1·35	84·2
Poplar	·39	24·3
„ White	·32 to ·51	20·0 to 31·8
„ 20 per cent. moisture	·48	29·9
Rosewood	1·03	64·2
Rock-Elm	·80	50·0
Satin-wood	·96	59·9
Service tree	·67	41·8
Sycamore	·59	36·8
Teak, African	·98	61·0
Vine tree	·60	37·4
Walnut, Green	·92	57·4
„ Brown	·68	42·4
Willow	·49	30·6
Yew	·74 to ·81	46·1 to 50·5
Yoke Elm, with 20 per cent. moisture	·76	47·5

INDIAN WOODS (Berkley).

Khair	1·17	73
Red Eyne	1·09	68
Erroul	1·01	63
Bibla	·90	56

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT
(continued).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
INDIAN WOODS (continued).		
Blackwood	·90	56
Northern Teak	·88	55
Southern Teak	·77	48
Jungle Teak	·66	41
Kullum	·66	41
Hedoo	·63	39
Poon	·63	39
BRITISH GUIANA (Fowke).		
Sipiri, or Green Heart	1·05 to 1·09	65·5 to 68·0
Wallaba	1·04	64·8
Brown Ebony	1·03	64·2
Letter Wood	1·00	62·4
Cuamara, or Tonka	·99	61·7
Monkey Pot	·94	58·6
Mora	·92	57·4
Ducaballi	·91	56·7
Cabacalli	·89	55·5
Kaieeballi	·87	54·2
Sirabuliballi	·84	52·4
Bukuradda	·81	50·5
Buckati	·81	50·5
Houbaballi	·81	50·5
Baracara	·81	50·5
White Cedar	·77	48·0
Locust tree	·71	44·3
Cartan	·70	43·7
Purple Heart	·68	42·4
Bartaballi	·64	39·4
Crabwood	·60	37·4
Silverballi	·55	34·3
JAMAICA (Fowke).		
Black Heart Ebony	1·19	74·2
Lignum-Vitæ	·65 to 1·17	40·5 to 73·0
Small Leaf	1·17	73·0
Neesberry Bullet tree	1·05	65·5
Red Bully tree	1·00	62·4
Iron Wood	·99	61·7
Sweet Wood	·97	60·5

TABLE 75. WEIGHT AND COMPOSITION OF BUILDING STONES (*continued*).

STONES.	Weight of One Cubic Foot.
3. MAGNESIAN LIMESTONES (<i>continued</i>)	
Huddlestane	137.8
Roche Abbey	139.1
Smawes	127.5
Average	136.0
4. GOLITH STONES.	
Ancaster, Lincolnshire	139.2
Barnack Mill, Northamptonshire	136.7
Bath Lodge Hill, Somersetshire	116.0
Bath Baynton	123.0
Bath (Drew's Quarry)	122.6
Crantmore, Wiltshire	134.2
Haydon, Lincolnshire	132.5
Ketton, Rutlandshire	128.3
Portland	126.3 to 142.0
Taynton, Oxon.	135.9
Wass, Yorkshire	soft, 141.7 hard, 162.6
Windrush, Gloucestershire	soft, 118.2 hard, 135.6
Average	133.5
5. SANDSTONES.	
Abercarne, Monmouth	147.9
Barbadoes, Tintern, Monmouth	146.7
Bunne, Lanlithgowshire	140.1
Bolton's Quarry, Yorkshire	126.7
Bramley Fall	112.2
Calverley, Kent	148.1
Craigleith, Edinburgh	145.9
Craw Bank, Lanlithgowshire	129.1
Duffield, Derbyshire	132.9
Duke's Quarries, Derbyshire	144.5
Elland Edge, Yorkshire	158.2
Ga'herley Moor	137.8
Ganton, Surrey	103.1
Gammis, Forfarshire	161.1
Heddon, Northumberland	130.7
Hollington, Staffordshire	133.1
Humble, Linlithgow	white, 140.0 grey, 135.7

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES (*continued.*)

STONES.		Weight of One Cubic Foot.			
5. SANDSTONES (<i>continued</i>).					
Longannet, Perthshire		131.7			
Munlochy, Ross-shire		160.6			
Mylnefield, Perthshire		160.0			
Park Spring, Yorkshire		151.1			
Pensber, Durham		134.3			
Pyot Dykes, Forfarshire		162.5			
Scotgate, Yorkshire		158.0			
Stancliff, Derbyshire		148.2			
Stenton, Durham		142.5			
Whitby Company's, Aislaby, Yorkshire		126.7			
" Egton "		127.9			
" Sneaton "		134.8			
" Newton Dale "		131.7			
Average		140.5			
6. MARBLES.					
Black, Kilkenny		171.4			
Tirec, Hebrides		172.3			
Carrara (Statuary), Tuscany		168.6			
" Ravaccione		169.1			
Ippilepen, Devonshire		163.4			
Average		169.0			
<i>General Composition of the above Stones.</i>					
STONES.	Carbonate of Lime.	Mag- nesia.	Silica.	Iron, Alumina, Water, and Loss.	Total.
	Per cent.	Pr. cent.	Pr. cent.	Per cent.	
Limestones	81.0	4.2	5	9.8	100.0
Do. Magnesian	54.6	40.6	2	2.8	100.0
Oolitic Stones	94.0	2.7	...	3.3	100.0
Sandstones	1.1	...	95.5	3.4	100.0
Marbles	lime	water .5	100.0
	56.5				
	carbonic acid				
	43.0				

TABLE 76.—BRICKS: DIMENSIONS AND WEIGHT.

(Hawkes.)

BRICKS.	Dimensions.			Weight of one brick	Weight of 1000 bricks
	in.	in.	in.	Pounds	Cwt.
London Stocks	8 $\frac{1}{2}$	4 $\frac{1}{2}$	2 $\frac{1}{2}$	6.81	60.78
Red Kail	8 $\frac{1}{2}$	4 $\frac{1}{2}$	2 $\frac{1}{2}$	7.00	63
Welsh Fire	9	4 $\frac{1}{2}$	2 $\frac{1}{2}$	7.84	65 to 70
Paving	9	4 $\frac{1}{2}$	1 $\frac{1}{2}$	5.00	45
Dutch Chinkers	6 $\frac{1}{2}$	3	1 $\frac{1}{2}$	1.55	14
Irish Fire	8 $\frac{1}{2}$	4 $\frac{1}{2}$	2 $\frac{3}{8}$	7.50	67
Worcester solid, machine made	..			8.75	78
Do. perforated	..			6.00	53.5
Staffordshire, solid, hand made	..			9.50	85
London stock, hand made	..			5.75	51

TABLE 77. MINERAL SUBSTANCES VARIOUS SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

S. SAMPLE	Specific Gravity	Weight of one Cubic Foot	Cubic Feet Ton
	Water 1	Pounds	Cubic
Alum	1.72	107.2	20.7
Asphalt	1.40	87.3	25.6
Ballast (brick rubbish and gravel)	1.80	112	20.0
Brick	2.00 to 2.17	124.7 to 135.3	18.1 to 16.6
	1.76 to 1.84	110	20.4
Brickwork	1.84	110	18
Camphor	.99	61.7	36.2
Clay	1.92	119.7	18.7
Coal			
Anthracite	1.37 to 1.59	85.4 to 99.1	26.2 to 22.6
	1.20 to 1.31	74.8 to 81.7	30.6 to 28.1
Bituminous	1.31	81.7	28.1
Boghead (Cannel)	1.20	78.4	30

TABLE 77.—MINERAL SUBSTANCES, VARIOUS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*).

SUBSTANCE.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Feet per Ton.
	Water 1.	Pounds.	Cubic Ft.
Earth, argillaceous:—			
Dry, loose	1.15 to 1.29	72 to 80	31.1 to 28
Dry, shaken	1.32 to 1.48	82 to 92	27.3 to 24.3
Moist, loose	1.06 to 1.22	66 to 76	34.0 to 29.5
Packed	1.44 to 1.60	90 to 100	24.8 to 22.4
Light vegetable	1.40	87.3	25.7
Glass:—			
Flint	3.00	187.0	12.0
Green	2.70	168.4	13.3
Plate	2.70	168.4	13.3
Thick flooring	2.53	158.0	14.2
Crown	2.50	155.9	14.4
St. Gobain	2.49	155.3	14.4
Common, with base of potash	2.46	153.4	14.6
Fine, with base of potash	2.45	152.8	14.6
Common, with base of soda	2.45	152.8	14.6
Fine, with base of soda	2.44	152.1	14.8
Gunpowder, heaped	1.75 to 1.84	109.1 to 114.7	20.5 to 19.5
	.922	57.5	39
Ice, melting	1.60 to 1.90	99.8 to 118.5	22.4 to 18.9
Marl			
Masonry:—			
Ashlar granite	2.37	147.5	15.2
„ Limestone, hard	2.70	168.5	11.4
„ „ semi-hard	2.42	151.9	14.8
„ „ soft	2.34	145.6	15.4
„ Millstone	2.01 to 2.51	125 to 156.2	18.0 to 14.3
„ Sandstone	2.61	162.5	13.2
Rubble, dry	2.21	138	16.2
„ mortar	2.47	154	14.6
Mortar, hardened	1.65	103	21.7

TABLE 77.—MINERAL SUBSTANCES, VARIOUS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*).

SUBSTANCE.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Foot per Ton.
	Water=1.	Pounds.	Cubic Ft.
Mud :—			
Dry, close	1.28 to 1.93	80.40 to 110	28.0 to 20.4
Wet, moderately pressed	1.93 to 2.09	110 to 130	20.4 to 17.2
Wet, fluid	1.67 to 1.92	104 to 120	21.5 to 18.7
Phosphorus	1.77	110.4	20.3
Plaster	1.57	98	22.9
Portland cement	1.25 to 1.51	78 to 94	28.7 to 23.8
Potash	2.10	131	17.1
Sand	1.44 to 1.87	90 to 117	24.9 to 19.1
„ saturated with water	1.89 to 2.07	118 to 129	19 to 17.4
Salt, common	1.92	119.7	18.7
„ rock	2.10 to 2.26	131 to 140.7	17.1 to 15.9
Sulphur	2.00	124.7	18.0
Tiles	2.00	124.7	18.0

TABLE 77a.—FUELS IN FRANCE.

	Weight of one Cub. Ft.	Specific Gravity.
	Pounds.	Water=1.
Pure graphite	145.3	2.38
Anthracite	83.5 to 91.0	1.34 to 1.40
Rich coal with a long flame	79.8 to 84.8	1.28 to 1.30
Dry coal with a long flame	84.8	1.36
Rich and hard coal	82.3	1.32
Smithy coal	79.8 to 81.1	1.28 to 1.30
Lignite	77.9 to 84.2	1.25 to 1.30
„ bituminous	72.3 to 74.8	1.16 to 1.20
„ imperfect	81.7	1.31
Bitumen, red	72.3	1.16
„ black	66.7	1.07
„ brown	51.7	0.83
Asphalte	66.1	1.06

TABLE 78.—WEIGHT AND VOLUME IN BULK OF VARIOUS SOLIDS.

(Tredgold.)

SUBSTANCE.	Weight of One Cubic Foot in bulk.	Volume of One Ton in bulk.
	Pounds.	Cubic Feet.
Lead, cast in pigs	567	4
Iron, cast in pigs	360	6.25
Limestone or Marble, in blocks	172	13
Granite, Aberdeen, in blocks	166	13.5
„ Cornish, „	164	14
Sandstone, in blocks	141	16
Portland Stone, in blocks	132	17
Potter's Clay	130	17
Loam or Strong Soil	126	18
Bath Stone, in blocks	123.5	18
Gravel.	109	21
Sand	95	23.5
Bricks, Common Stock, dry	98	24
Culm	63	36
Water, River	62.5	36
Splint Coal	57	39.5
Oak, Seasoned	52	43
Coal (Newcastle) caking	50	45
Wheat	48	47
Barley	38	59
Red Fir	38	59
Hay, compact, old	8	280

TABLE 79.—MEASURES OF ORES, EARTH, &C.

(Rand Drill Company.)

	Weight.
14.5 Cubic Feet of ordinary Gold or Silver Ore, in mine	1 ton
22 „ of Broken Quartz	1 „
20 „ Gravel, in bank	1 „
30 „ Gravel, when dry	1 „
28 „ Sand	1 „
20 „ Earth, in bank	1 „
30 „ „ when dry	1 „
19 „ Clay	1 „
45 „ Bituminous Coal, heaped	1 „
42 „ Anthracite	1 „
123 „ Charcoal	1 „
71 „ Coke	1 „

		Weight.	Equivalent Foil to
1	Cubic Foot Anthracite, heaped	50 lb. to 55	
1	" Bituminous Coal "	45 lb. to 55	
1	" Cumberland Coal	53 lb.	
1	" Canal Coal	50½ lb.	
1	" Hardwood Charcoal	18½ lb.	
1	" Pine Charcoal	18 lb.	
		Weight.	Equivalent Foil to
1	Cord of Wood, 4 feet x 4 feet x 8 feet		128 cubic feet
1	Cord of air-dried Hickory or Hard Maple	4,500 lb.	2,000 lb. 00
1	" " White Oak	3,850 "	1,715 "
1	" " Beech, Red Oak or Black Oak	3,250 "	1,450 "
1	" " Poplar (white wood), Chest- nut, or Elm	2,350 "	1,050 "
1	" " Average Pine	2,000 "	925 "

TABLE 80. FUELS. SPECIFIC GRAVITY, WEIGHT, AND
BULK

Fuels.	Specific Gravity.	Weight of One Cubic Foot.		Volume of one Ton heaped.
		Solid.	Heaped.	
COALS.				
Anthracite	1.37	85.4	58.3	38.4
.. American	1.30 to 1.84	83.5	54.0	...
Welsh	1.32	82.3	53.1	42.7
Newcastle	1.25	78.3	49.8	45.3
Derbyshire and Yorkshire	1.29	79.6	45.9	47.4
Lancashire	1.27	79.4	49.7	45.2
Scotch	1.26	78.6	50.0	42.0
Irish Slieve Donagh anthracite	1.59	99.6	62.8	35.7
Bituminous coal, American	1.35	84.0	50.0	...
Boghead (Scotland)	1.18	..	..	...
COKE.				
Coke generally		40 to 50	30.0	70 to 80
Tanfield . . . . .	.74	46	30.0	74.7

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water—1.	Lbs.	Lbs.	Cub. Ft.
COKE (<i>continued</i>).				
Gas coke . . . . .	...	...	23·8 to 28·6	...
American . . . . .	...	...	32·1	69·8
Seraing (France) . . . . .	...	...	31·0	72·0
Graphite	2·33	145·3	...	...
LIGNITE AND ASPHALTE.				
Perfect lignite	1·29	...	...	...
Imperfect lignite	1·15	...	...	...
Bituminous lignite	1·18	...	...	...
Asphalte	1·06	...	...	...
WOOD.—See Table 81.				
WOOD CHARCOAL.				
<i>As made, heaped.</i>				
Oak and beech	·24 to	...	15 to	...
	·25	...	15·6	...
Birch	·22 to	...	13·7 to	...
	·23	...	14·3	...
Pine	·20 to	...	12·5 to	...
	·21	...	13·1	...
Average	·225	...	14	...
<i>In small pieces, heaped.</i>				
Walnut	·63	...	39·3	...
Ash	·53	...	34·3	...
Beech	·52	...	32·5	...
Yoke-Elm	·46	...	28·7	...
Appleton	·46	...	28·7	...
White oak	·42	...	26·2	...
Cherry tree	·41	...	25·6	...
Birch	·36	...	22·5	...
Elm	·36	...	22·5	...
Yellow pine	·33	...	20·6	...
Chestnut tree	·28	...	17·5	...
Poplar	·25	...	15·6	...
Cedar	·24	...	15·0	...
Average	·405	...	25·3	...

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (continued).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
<i>As Powder.</i>				
Willow	1.55	...	96.7	...
Oak	1.53	...	95.4	...
Alder	1.49	...	92.9	...
Lime tree	1.46	...	91.0	...
Poplar	1.45	...	90.4	...
Average	1.50	...	98.5	...
Gunpowder, loose . . . . .	.90	...	...	...
" shaken	1.00	...	...	...
" solid	1.55 to 1.80	...	...	...
<i>Irish Peat.</i>				
Very light, spongy, surface peat . . . . .	.22 to .34	13.7 to 21.0	...	...
Light surface peat . . . . .	.34 to .41	20.9 to 25.3	...	...
Rather dense . . . . .	.48 to .67	29.7 to 41.7	...	...
Very dense, dark brown . . . . .	.65 to .71	40.5 to 44.5	...	...
Very dense, blackish brown, compact . . . . .	.72 to .98	45.1 to 61.3	...	...
Exceedingly dense, jet black . . . . .	.73 to .99	53.2 to 61.8	...	...
Exceedingly dense, dark blackish brown	1.00	66.0	...	...
Upper moss . . . . .	...	...	6.06 to 8.81	569.6 to 254.2
Brown . . . . .	...	...	15.13	147.0
Compact black . . . . .	...	...	17.06	131.3
Densest black . . . . .	...	...	22.54	90.4
Condensed peat	1.0 to 1.3	62.5 to 81.1	43.7 to 56.8	51.2 to 40.0

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT.

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Acacia . . . . .	.82	51.1
„ with 20 per cent. moisture	.72	44.9
Alder tree . . . . .	.56	34.9
„ with 20 per cent. moisture	.60	37.4
Ash . . . . .	.84	52.4
„ with 20 per cent. moisture	.70	43.7
Aspen tree . . . . .	.60	37.4
Apple tree . . . . .	.73	45.5
Bamboo . . . . .	.31 to .40	19.5 to 24.9
Beech . . . . .	.75 to .85	46.8 to 50.3
„ with 20 per cent. moisture	.82	51.1
„ cut one year . . . . .	.66	41.2
Birch . . . . .	.72 to .74	44.9 to 46.1
Boxwood	1.04	64.8
Cedar of Lebanon . . . . .	.49 to .57	30.6 to 35.5
Cork . . . . .	.24	15.0
Cypress, cut one year . . . . .	.66	41.2
Ebony	1.13	70.5
„ Green	1.21	75.5
„ Black	1.19	74.2
Elder path . . . . .	.076	4.74
Elm . . . . .	.55	34.3
„ Green . . . . .	.76	47.5
„ with 20 per cent. moisture	.72	44.9
Fir, Norway Pine . . . . .	.74	46.1
„ Red Pine . . . . .	.48 to .70	29.9 to 43.7
„ Spruce . . . . .	.48 to .70	29.9 to 43.7
„ Larch . . . . .	.50 to .64	31.2 to 39.9
„ White Pine, English . . . . .	.55	34.3
„ „ Scotch . . . . .	.53	34.3
„ „ „ with 20 per cent. moisture . . . . .	.49	30.6
„ Yellow Pine . . . . .	.66	41.2
„ „ American . . . . .	.46	28.7
Hawthorn . . . . .	.91	56.7
Holly . . . . .	.76	47.5
Hornbeam . . . . .	.76	47.5
Laburnum . . . . .	.92	57.4
Lance Wood . . . . .	.67 to 1.01	41.8 to 63.6
Lignum-Vitæ . . . . .	.65 to 1.33	40.5 to 82.9

TABLE 81.—WOODS. SPECIFIC GRAVITY AND WEIGHT
(continued).

Woods.	Specific Gravity.	Weight of One Cubic Foot.
	Water 1	Pounds.
Mahogany, Spanish . . . . .	.85	53.0
" St. Domingo . . . . .	.75	46.8
" Cuba . . . . .	.56	34.9
" Honduras . . . . .	.56	34.9
Maple . . . . .	.65	40.5
20 per cent. moisture . . . . .	.67	41.8
Mulberry . . . . .	.89	55.5
Oak Heart of	1.17	73.0
" English . . . . .	.98	58.0
" European . . . . .	.69 to .99	43.0 to 61.7
" American Red . . . . .	.87	54.2
Olive tree . . . . .	.68	42.4
Orange tree . . . . .	.71	44.3
Pear tree . . . . .	.73	45.3
Plane tree . . . . .	.65	40.5
Plum tree . . . . .	.87	54.2
Pomegranate	1.35	84.2
Poplar . . . . .	.39	24.3
" White . . . . .	.32 to .51	20.0 to 31.8
" 20 per cent. moisture . . . . .	.48	29.9
Rosewood	1.03	64.2
Rock Elm . . . . .	.80	50.0
Satin-wood . . . . .	.96	59.9
Service tree . . . . .	.67	41.8
Sycamore . . . . .	.59	36.8
Tenk, African . . . . .	.98	61.0
Vine tree . . . . .	.60	37.4
Walnut, Green . . . . .	.62	37.4
" Brown . . . . .	.68	42.4
Willow . . . . .	.49	30.6
Yew . . . . .	.74 to .81	46.1 to 50.5
Yoke Elm, with 20 per cent. moisture . . . . .	.76	47.5

INDIAN WOODS (Berkley).

Khair	1.17	73
Red Eyno	1.09	68
Erroul	1.01	63
Bibla . . . . .	.90	56

TABLE 81.—WOODS : SPECIFIC GRAVITY AND WEIGHT
(continued).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
INDIAN WOODS (continued).		
Blackwood	·90	56
Northern Teak	·88	55
Southern Teak	·77	48
Jungle Teak	·66	41
Kullum	·66	41
Hedoo	·63	39
Poon	·63	39
BRITISH GUIANA (Fowke).		
Sipiri, or Green Heart	1·05 to 1·09	65·5 to 68·0
Wallaba	1·04	64·8
Brown Ebony	1·03	64·2
Letter Wood	1·00	62·4
Cuamara, or Tonka	·99	61·7
Monkey Pot	·94	58·6
Mora	·92	57·4
Ducaballi	·91	56·7
Cabacalli	·89	55·5
Kaieeballi	·87	54·2
Sirabuliballi	·84	52·4
Buhuradda	·81	50·5
Buckati	·81	50·5
Houbaballi	·81	50·5
Baracara	·81	50·5
White Cedar	·77	48·0
Locust tree	·71	44·3
Cartan	·70	43·7
Purple Heart	·68	42·4
Bartaballi	·64	39·4
Crabwood	·60	37·4
Silverballi	·55	34·3
JAMAICA (Fowke).		
Black Heart Ebony	1·19	74·2
Lignum-Vitæ	·65 to 1·17	40·5 to 73·0
Small Leaf	1·17	73·0
Neesberry Bullet tree	1·05	65·5
Red Bully tree	1·00	62·4
Iron Wood	·99	61·7
Sweet Wood	·97	60·5

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT
(continued).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
JAMAICA (continued).		
Fustic	.97	60.5
Satin Candlewood	.96	59.9
Bastard Cabbage Dark	.94	58.6
White Dogwood	.94	58.6
Black "	.93	58.0
Gynip	.93	58.0
Wild Mahogany	.92	57.4
Cashaw	.92	57.4
Wild Orange	.85 to .91	53.0 to 58.7
Sweet Orange	.79	49.3
Bullet tree (bastard)	.90	56.1
Tamarind	.87	54.2
" wild	.75	46.8
Prune	.86	53.6
Yellow Sanders	.86	53.6
Beech	.84	52.4
French Oak	.77	48.0
Broad Leaf	.77	48.0
Fiddlewood	.71	44.3
Prickle Yellow	.59	43.0
Boxwood	.59	43.0
Locust tree	.58	42.4
Lance Wood	.58	42.4
Green Mahogany	.56	41.2
Yacca	.53	39.3
Cedar	.58	36.2
Calabash	.56	34.9
Bitter Wood	.55	34.3
Blue Mahoe	.54	33.7

NEW SOUTH WALES.

Box of Ilwara	1.17	73.0
" Bastard	1.12	69.8
" True, of Camden	.97	60.5
Mountain Ash	1.11	69.2
Kakaralli	1.10	68.6
Iron Bark	1.03	64.2
" broad leaved	1.02	63.6
Woolly Butt	1.01	63.0
Black "	.89	55.5

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT
(continued).

WOOD.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
NEW SOUTH WALES (continued).		
Water Gum	1.00	62.4
Blue Gum . . . . .	.84	52.4
Cog Wood . . . . .	.96	59.9
Mahogany . . . . .	.95	59.2
" Swamp . . . . .	.86	53.6
Gray Gum . . . . .	.93	58.0
Stringy Bark . . . . .	.86	53.6
Hickory . . . . .	.75	46.8
Forest Swamp Oak . . . . .	.56	41.2

TABLE 82.—ANIMAL SUBSTANCES: SPECIFIC GRAVITY AND WEIGHT.
(Claudel.)

SUBSTANCE.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Pearls	2.72	169.6
Coral	2.69	167.7
Ivory	1.82 to 1.92	114 to 119.7
Bone	1.80 to 2.00	112.2 to 124.7
Wool	1.31	100.4
Tendon	1.12	69.8
Cartilage	1.09	68.0
Crystalline humour	1.08	67.3
Human Body	1.07	66.7
Nerve	1.04	64.9
Bees Wax . . . . .	.96	59.2
Lard . . . . .	.95	59.3
Spermaceti . . . . .	.94	58.8
White of Whalebone . . . . .	.94	58.7
Butter . . . . .	.94	58.7
Pork Fat . . . . .	.94	58.7
Tallow . . . . .	.92	57.5
Beef Fat . . . . .	.92	57.5
Mutton Fat . . . . .	.92	57.4
Animal Charcoal, in heaps . . . . .	.80 to .83	50 to 52

TABLE 83.—VEGETABLE SUBSTANCES: SPECIFIC GRAVITY
AND WEIGHT.

SUBSTANCE.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Cotton	1.95	121.6
Flax	1.79	111.6
Starch	1.53	95.4
Fecula	1.50	93.5
Gum, Arabic	1.45	...
„ Mastic	1.07	66.7
Resin, Guayacum	1.20	74.8
„ Benzoin	1.09	68.0
Indigo	1.009	...
Sugar	1.005	...
Amber	1.09	68.0
Gutta-percha . . . . .	.97	60.5
India-rubber . . . . .	.93	58.0
	Weight of One Cubic Foot, loosely filled.	Weight of One Cubic Foot, closely filled.
Grain :—		
Wheat, Red Winter	49	53½
„ Bombay	49	53
„ California	49	53
„ Walla-Walla	46	50½
„ Bessarabia	49	53
Peas, American	50	54
Indian Corn, White American	43½	47
„ Mixed	44	47
Oats, Russian	28	33
Beans, Egyptian	46	50
Barley, English	39	44

Note.—Under the Corn Returns Act, 1882, the bushel of the following grains is, for statistical purposes, to be taken respectively :—

For Wheat as	60 lb.
For Barley as	50 lb.
For Oats as	39 lb.

TABLE 84.—LIQUIDS:—SPECIFIC GRAVITY AND WEIGHT.

LIQUIDS AT 32° F.	Specific Gravity.	Weight of One Cubic Foot.	Weight of One Gallon,
	Water=1.	Pounds.	Pounds.
Mercury	13·596	848·7	136·0
Sulphuric Acid, maximum concentration	1·84	114·9	18·4
Nitrous Acid	1·55	96·8	15·5
Chloroform	1·53	95·5	15·3
Nitric acid, of commerce	1·22	76·2	12·2
Acetic acid, maximum concentration	1·08	67·4	10·8
Milk	1·03	64·3	10·3
Sea Water, ordinary	1·026	64·05	10·3
Pure Water, at 39·0° F.	1·000	62·425	10·0112
Wine, Red	·99	62·0	9·9
Oil, Linseed	·94	58·7	9·4
„ Rapeseed	·92	57·4	9·2
„ Whale	·92	57·4	9·2
„ Olive	·915	57·1	9·15
„ Turpentine	·87	54·3	8·7
Tar	1·00	62·4	10·0
Petroleum	·88	54·9	8·8
Naphtha	·85	53·1	8·5
Ether, Nitric	1·11	69·3	11·1
„ Sulphurous	1·08	67·4	10·8
„ Nitrous	·89	55·6	8·9
„ Acetic	·89	55·6	8·9
„ Hydrochloric	·87	54·3	8·7
„ Sulphuric	·72	44·9	7·2
Alcohol, proof spirit	·92	57·4	9·2
„ pure	·79	49·3	7·9
Benzine	·85	53·1	8·5
Proof Spirit	·80	49·9	8·0

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (continued).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
<i>As Powder.</i>				
Willow	1.55	...	96.7	...
Oak	1.53	...	95.4	...
Alder	1.49	...	92.9	...
Lime tree	1.46	...	91.0	...
Poplar	1.45	...	90.4	...
Average	1.50	...	98.5	...
Gunpowder, loose	.90	...	...	...
" shaken	1.00	...	...	...
" solid	1.55 to 1.80	...	...	...
<i>Irish Peat.</i>				
Very light, spongy, surface peat	.22 to .34	13.7 to 21.0	...	...
Light surface peat	.34 to .41	20.9 to 25.3	...	...
Rather dense	.48 to .67	29.7 to 41.7	...	...
Very dense, dark brown	.65 to .71	40.5 to 44.5	...	...
Very dense, blackish brown, compact	.72 to .98	45.1 to 61.3	...	...
Exceedingly dense, jet black	.73 to .99	53.2 to 61.8	...	...
Exceedingly dense, dark blackish brown	1.03	66.0	...	...
Upper moss	...	...	6.06 to 8.81	369.6 to 254.2
Brown	...	...	15.13	147.0
Compact black	...	...	17.06	131.3
Densest black	...	...	22.54	99.4
Condensed peat	1.0 to 1.3	62.5 to 81.1	43.7 to 56.8	51.2 to 40.0

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT.

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Acacia . . . . .	.82	51.1
„ with 20 per cent. moisture	.72	44.9
Alder tree . . . . .	.56	34.9
„ with 20 per cent. moisture	.60	37.4
Ash . . . . .	.84	52.4
„ with 20 per cent. moisture	.70	43.7
Aspen tree . . . . .	.60	37.4
Apple tree . . . . .	.73	45.5
Bamboo . . . . .	.31 to .40	19.5 to 24.9
Beech . . . . .	.75 to .85	46.8 to 50.3
„ with 20 per cent. moisture	.82	51.1
„ cut one year . . . . .	.66	41.2
Birch . . . . .	.72 to .74	44.9 to 46.1
Boxwood	1.04	64.8
Cedar of Lebanon . . . . .	.49 to .57	30.6 to 35.5
Cork . . . . .	.24	15.0
Cypress, cut one year . . . . .	.66	41.2
Ebony	1.13	70.5
„ Green	1.21	75.5
„ Black	1.19	74.2
Elder path . . . . .	.076	4.74
Elm . . . . .	.55	34.3
„ Green . . . . .	.76	47.5
„ with 20 per cent. moisture	.72	44.9
Fir, Norway Pine . . . . .	.74	46.1
„ Red Pine . . . . .	.48 to .70	29.9 to 43.7
„ Spruce . . . . .	.48 to .70	29.9 to 43.7
„ Larch . . . . .	.50 to .64	31.2 to 39.9
„ White Pine, English . . . . .	.55	34.3
„ „ Scotch . . . . .	.53	34.3
„ „ „ with 20 per cent. moisture . . . . .	.49	30.6
„ Yellow Pine . . . . .	.66	41.2
„ „ „ American . . . . .	.46	28.7
Hawthorn . . . . .	.91	56.7
Holly . . . . .	.76	47.5
Hornbeam . . . . .	.76	47.5
Laburnum . . . . .	.92	57.4
Lance-Wood . . . . .	.67 to 1.01	41.8 to 63.9
Lignum-Vita . . . . .	.65 to 1.33	40.5 to 82.9

TABLE 81.—WOODS : SPECIFIC GRAVITY AND WEIGHT
(continued).

WOOD.	Specific Gravity.	Weight of One Cubic Foot.
	Water=1.	Pounds.
Mahogany, Spanish	·85	53·0
„ St. Domingo	·75	46·8
„ Cuba	·56	34·9
„ Honduras	·56	34·9
Maple	·65	40·5
„ 20 per cent. moisture	·67	41·8
Mulberry	·89	55·5
Oak, Heart of	1·17	73·0
„ English	·93	58·0
„ European	·69 to ·99	43·0 to 61·7
„ American Red	·87	54·2
Olive tree	·68	42·4
Orange tree	·71	44·3
Pear tree	·73	45·3
Plane tree	·65	40·5
Plum tree	·87	54·2
Pomegranate	1·35	84·2
Poplar	·39	24·3
„ White	·32 to ·51	20·0 to 31·8
„ 20 per cent. moisture	·48	29·9
Rosewood	1·03	64·2
Rock-Elm	·80	50·0
Satin-wood	·96	59·9
Service tree	·67	41·8
Sycamore	·59	36·8
Teak, African	·98	61·0
Vine tree	·60	37·4
Walnut, Green	·92	57·4
„ Brown	·68	42·4
Willow	·49	30·6
Yew	·74 to ·81	46·1 to 50·5
Yoke Elm, with 20 per cent. moisture	·76	47·5

INDIAN WOODS (Berkley).

Khair	1·17	73
Red Eyne	1·09	68
Erroul	1·01	63
Bibla	·90	56

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT
(*continued*).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
INDIAN WOODS (<i>continued</i>).		
Blackwood	·90	56
Northern Teak	·88	55
Southern Teak	·77	48
Jungle Teak	·66	41
Kullum	·66	41
Hedoo	·63	39
Poon	·63	39
BRITISH GUIANA (Fowke).		
Sipiri, or Green Heart	1·05 to 1·09	65·5 to 68·0
Wallaba	1·04	64·8
Brown Ebony	1·03	64·2
Letter Wood	1·00	62·4
Cuamara, or Tonka	·99	61·7
Monkey Pot	·94	58·6
Mora	·92	57·4
Ducaballi	·91	56·7
Cabacalli	·89	55·5
Kaieeballi	·87	54·2
Sirabuliballi	·84	52·4
Buhuradda	·81	50·5
Buckati	·81	50·5
Houbaballi	·81	50·5
Baracara	·81	50·5
White Cedar	·77	48·0
Locust tree	·71	44·3
Cartan	·70	43·7
Purple Heart	·68	42·4
Bartaballi	·64	39·4
Crabwood	·60	37·4
Silverballi	·55	34·3
JAMAICA (Fowke).		
Black Heart Ebony	1·19	74·2
Lignum-Vitæ	·65 to 1·17	40·5 to 73·0
Small Leaf	1·17	73·0
Neesberry Bullet tree	1·05	65·5
Red Bully tree	1·00	62·4
Iron Wood	·99	61·7
Sweet Wood	·97	60·5

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT
(continued).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
JAMAICA (continued).		
Fustic . . . . .	.97	60.5
Satin Candlewood . . . . .	.96	59.9
Bastard Cabbage Bark . . . . .	.94	58.6
White Dogwood . . . . .	.94	58.6
Black " . . . . .	.93	58.0
Gynip . . . . .	.93	58.0
Wild Mahogany . . . . .	.92	57.4
Cashaw . . . . .	.92	57.4
Wild Orange . . . . .	.85 to .91	53.0 to 54.7
Sweet Orange . . . . .	.79	49.3
Bullet tree (bastard) . . . . .	.90	56.1
Tamarind . . . . .	.87	54.2
" wild . . . . .	.75	46.8
Prune . . . . .	.86	53.6
Yellow Sanders . . . . .	.86	53.6
Beech . . . . .	.84	52.4
French Oak . . . . .	.77	48.0
Broad Leaf . . . . .	.77	48.0
Fiddlewood . . . . .	.71	44.3
Prickle Yellow . . . . .	.39	43.0
Boxwood . . . . .	.39	43.0
Locust tree . . . . .	.38	42.4
Lance Wood . . . . .	.38	42.4
Green Mahogany . . . . .	.36	41.2
Yacca . . . . .	.33	39.3
Cedar . . . . .	.58	36.2
Calabash . . . . .	.56	34.9
Bitter Wood . . . . .	.55	34.3
Blue Mahoe . . . . .	.54	33.7
NEW SOUTH WALES.		
Box of Ilwara	1.17	73.0
" Bastard	1.12	69.8
" True, of Camden . . . . .	.97	60.5
Mountain Ash	1.11	69.2
Kakaralli	1.10	68.6
Iron Bark	1.03	64.2
" broad leaved	1.02	63.6
Woolly Butt	1.01	63.0
Black " . . . . .	.89	55.5

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
COKE (<i>continued</i>).				
Gas coke . . . . .	...	...	23·8 to 28·6	...
American . . . . .	...	...	32·1	69·8
Seraing (France) . . . . .	...	...	31·0	72·0
Graphite	2·33	145·3	...	...
LIGNITE AND ASPHALTE.				
Perfect lignite	1·29	...	...	...
Imperfect lignite	1·15	...	...	...
Bituminous lignite	1·18	...	...	...
Asphalte	1·06	...	...	...
WOOD.—See Table 81.				
WOOD CHARCOAL.				
<i>As made, heaped.</i>				
Oak and beech	24 to	...	15 to	...
	25		15·6	
Birch	22 to	...	13·7 to	...
	23		14·3	
Pine	20 to	...	12·5 to	...
	21		13·1	
Average	22·5	...	14	...
<i>In small pieces, heaped.</i>				
Walnut	·63	...	39·3	...
Ash	·53	...	34·3	...
Beech	·52	...	32·5	...
Yoke-Elm	·46	...	28·7	...
Appleton	·46	...	28·7	...
White oak	·42	...	26·2	...
Cherry tree	·41	...	25·6	...
Birch	·36	...	22·5	...
Elm	·36	...	22·5	...
Yellow pine	·33	...	20·6	...
Chestnut tree	·28	...	17·5	...
Poplar	·25	...	15·6	...
Cedar	·24	...	15·0	...
Average	·405	...	25·3	...

TABLE 85. -WEIGHT AND SPECIFIC GRAVITY OF OILS
(Stilwell.)

OILS AT 70° F.	Weight of One Gallon	Specific Gravity
	Pounds.	Water = 1
Sperm, bleached, winter	8.81	.881
" natural, winter	8.81	.881
Elaine	9.01	.901
Recd, saponified	9.02	.902
Lahn	9.05	.905
Lallow	9.14	.914
Neatsfoot	9.14	.914
Rape-seed, white, winter	9.14	.914
Olive light greenish, yellow	9.14	.914
" dark green	9.14	.914
Peanut	9.15	.915
Olive, virgin, very light yellow	9.16	.916
Rape-seed, dark yellow	9.17	.917
Olive virgin, dark clear yellow	9.17	.917
Lard, winter	9.17	.917
Sea Elephant	9.20	.920
Tanner's Cod	9.20	.920
Cotton-seed, raw	9.22	.922
" refined, yellow	9.23	.923
Sisal (cotton-seed)	9.23	.923
Labrador (cod)	9.24	.924
Flax	9.24	.924
Seal, natural	9.25	.925
Cocconut	9.25	.925
Whale, natural, winter	9.25	.925
" bleached, winter	9.26	.926
Cod liver, pure	9.27	.927
Seal raked	9.29	.929
Cotton-seed, white, winter	9.29	.929
Strait (cod)	9.29	.929
Mahadon, dark	9.29	.929
Lard seed (raw)	9.30	.930
Bark (cod)	9.32	.932
Mahadon, light	9.32	.932
Porgy	9.33	.933
Lard seed, boiled	9.41	.941
Castor, pure cold pressed	9.67	.967
Rose third run	9.89	.989

TABLE 86.—GASES AND VAPOURS.—SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

GASES at 32° F., and under one Atmosphere of Pressure.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Pound Weight.
		Pounds.	Ounces.	
	Air = 1.			Cub. Ft.
Mercury	6·9740	·563	9·008	1·776
Chloroform	5·3000	·428	6·846	2·337
Turpentine	4·6978	·378	6·042	2·637
Acetic Ether	3·0400	·245	3·927	4·075
Benzine	2·6943	·217	3·480	4·598
Sulphuric Ether	2·5860	·209	3·340	4·790
Chlorine	2·4400	·197	3·152	5·077
Sulphurous Acid	2·2470	·1814	2·902	5·513
Alcohol	1·6130	·1302	2·083	7·679
Carbonic Acid	1·5290	·12344	1·975	8·101
Oxygen	1·1056	·089253	1·428	11·205
Air	1·0000	·080728	1·29165	12·387
Nitrogen	·9736	·078596	1·258	12·723
Carbonic Oxide	·9674	·0781	1·250	12·804
Oleflant Gas	·9847	·0795	1·272	12·580
Ammoniacal Gas	·5894	·04758	7·613	21·017
Light Carburetted Hydrogen	·5527	·04462	·7139	22·412
Coal Gas	·4381	·03536	·5658	28·279
Hydrogen	·0692	·005592	·0895	178·83

TABLE 87.—WEIGHT AND VOLUME OF BODIES.

(Tol.)

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
METALS.				
Antimony, cast	6,702	418·8750	3·8748	3·8866
Zinc, cast	7,190	449·3750	4·1608	3·8431
Iron, cast	7,207	450·4375	4·1707	3·8364
Tin, cast	7,291	455·6875	4·2193	3·7920
„ hardened	7,299	456·1875	4·2239	3·7878
Pewter	7,471	466·9375	4·3234	3·7007

TABLE 87. WEIGHT AND VOLUME OF BODIES (continued)

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.		
METALS (continued).				
Iron, bar	7,788	486.7500	4.5069	3.5500
Cobalt, cast	7,811	488.1875	4.5202	3.5306
Steel, hard	7,816	488.5000	4.5231	3.5278
" soft meteoric	7,833	489.5625	4.5329	3.5206
Iron, hammered	7,965	497.8125	4.6693	3.4702
Nickel, cast	8,279	517.4375	4.7915	3.3305
Brass, cast	8,395	524.6875	4.8782	3.2933
" wire	8,541	534.0000	4.9111	3.2350
Nickel, hammered	8,666	541.6250	5.0150	3.1904
Gun metal	8,784	549.0000	5.0833	3.1476
Copper, cast	8,788	549.3750	5.0856	3.1461
" wire	8,878	554.8750	5.1577	3.1140
" coin	8,917	557.1875	5.1791	3.0959
Bismuth, cast	9,822	613.8750	5.6840	2.8149
Silver, hammered	10,510	656.8750	6.0821	2.6306
" coin	10,531	658.5625	6.0960	2.6216
" pure, cast	10,744	671.5000	6.2175	2.5793
Rhodium	11,000	687.5000	6.3677	2.5134
Lead, cast	11,352	709.5000	6.5004	2.4375
Palladium	18,000	1125.0000	6.8287	2.5134
Mercury (quicksilver), (mm)	13,608	850.0000	7.8518	2.0357
" pure	14,000	875.0000	8.1018	1.9618
Gold, trunket	15,000	937.5000	8.6008	1.7600
" coin	17,547	1096.6875	10.2123	1.6124
" pure cast	19,278	1203.6250	11.1116	1.4356
" hammered	19,306	1210.0625	11.2042	1.4280
Platinum, pure	19,600	1218.7500	11.2844	1.4178
" hammered	21,336	1333.0000	11.7687	1.3595
" wire	23,541	1471.5625	12.1705	1.3119
" laminated	22,069	1379.3125	12.7711	1.2528
Ir. lam. hammered	23,000	1437.5000	13.3101	1.2021
EARTH, STONES &c				
Amber	1.078	67.3750	0.62384	25.6474
Coal	1.250	78.7500	0.72334	21.9428
Sand	1.300	81.7500	0.80803	18.4320
Brick	2.000	125.0000	1.15470	13.8240

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
EARTH, STONES, &c. (<i>continued</i>).				
Sulphur, native	2,033	127·0625	1·17650	13·5996
Opal	2,114	132·1250	1·22337	13·0785
Clay	2,160	135·0000	1·25000	12·8000
Gypsum	2,280	142·5000	1·31944	12·1263
Porcelain, Limoges	2,341	146·3125	1·35474	11·8103
" China	2,385	147·2500	1·38020	11·7351
Stone, paving	2,416	151·4000	1·39814	11·4437
" common	2,520	157·5000	1·45833	10·9714
Flint	2,594	162·1250	1·50115	10·6584
Spar	2,594	162·1250	1·50115	10·6584
Pebble, English	2,619	163·6875	1·51562	10·5566
Granite, Aberdeen	2,625	164·0625	1·51909	10·5325
Quartz	2,640	165·0000	1·52777	10·4727
Glass, green	2,642	165·1250	1·52893	10·4648
Crystal, rock	2,653	165·8125	1·53530	10·4214
Granite, red Egyptian	2,654	165·8750	1·53587	10·4175
" Cornish	2,662	166·3750	1·53935	10·3861
Marble, Egyptian	2,668	166·7500	1·54976	10·3628
Slate	2,672	167·0000	1·54629	10·3473
Coral	2,680	167·5000	1·55092	10·3164
Pearl, Oriental	2,684	167·7500	1·55324	10·3010
Glass, bottle	2,733	170·8125	1·58159	10·1163
Marble, green Campanian	2,742	171·3750	1·58735	10·0831
Emerald of Peru	2,775	173·4375	1·60590	9·3632
Chalk, British	2,784	174·0000	1·61111	9·9310
Marble, Parian	2,837	177·3125	1·64178	9·7455
Basalt, Giants' Causeway	2,864	179·0000	1·65740	9·6536
Glass, white	2,892	180·7500	1·67361	9·5601
Limestone	2,950	184·3750	1·70717	9·3721
Asbestos	2,996	187·2500	1·73379	9·2283
Hornblende	3,000	187·5000	1·73611	9·2160
White Lead	3,160	197·5000	1·82870	8·7493
Glass, British flint	3,329	208·0625	1·92650	8·3052
Diamond, average	3,536	221·0000	2·04629	7·8190
Beryl, Oriental	3,549	221·8125	2·05381	7·7903

TABLE 87. — WEIGHT AND VOLUME OF BODIES *(continued)*.

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
EARTH, STONES, &c. <i>(continued)</i> .				
Garnet, common . . .	3.576	223.5080	2.03944	7.7315
Topaz, average . . .	3.804	237.5080	2.19907	7.2800
Sapphire, Oriental . .	3.994	243.3750	2.25347	7.1001
Garnet, precious . . .	4.280	264.3750	2.44791	6.5361
Ruby, Oriental . . .	4.283	267.6875	2.47858	6.4590
Jargon of Ceylon . . .	4.416	276.0000	2.55555	6.2608
Spar, heavy . . .	4.430	276.8750	2.56365	6.2410
Leadstone . . .	4.930	308.1250	2.85300	5.6081
The earth (mean of the globe) . . .	5.210	325.6250	3.01504	5.3067
RESINS, GUMS, &c.				
Gunpowder loose heap	836	52.2500	0.48379	33.0717
Living men . . .	891	55.6875	0.51562	31.0303
Wax . . .	897	56.0625	0.51909	30.8227
Ice . . .	930	58.1250	0.53819	29.7298
Gunpowder, close shaken	937	58.5625	0.54224	29.5069
Tallow . . .	942	58.8750	0.54513	29.3506
Butter . . .	942	58.8750	0.54513	29.3506
Beeswax . . .	956	59.7500	0.55324	28.9206
Sassafras . . .	972	60.7500	0.56250	28.4444
Camphor . . .	980	61.8125	0.56655	27.9532
Resin . . .	1.100	68.7000	0.63657	25.0906
Put . . .	1.150	71.8750	0.66550	24.0417
Opium . . .	1.337	83.5625	0.77472	20.6791
Gum Arabic . . .	1.42	90.7500	0.84627	19.0412
Honey . . .	1.46	91.0000	0.84259	18.9880
Bone of an ox . . .	1.679	103.6875	0.96006	16.6654
" dry " . . .	1.680	103.7500	0.96061	16.6554
Phosphorus . . .	1.714	107.1250	0.99184	16.1301
Alum . . .	1.714	107.1250	0.99184	16.1301
Gunpowder, solid . . .	1.745	109.0625	1.00083	15.8441
Nitre (saltpetre) . . .	1.900	118.7500	1.03953	14.5512
Ivory . . .	1.917	119.8125	1.10937	14.4425
WOODS.				
Cork . . .	240	15.0000	0.13888	115.2000

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
WOODS (<i>continued</i>).				
Poplar	383	23.9375	0.22164	71.7660
Larch	344	34.0000	0.31481	50.8235
Fir, North of England	356	34.7500	0.32175	49.7266
Mahogany, Honduras .	360	35.0000	0.32407	49.3714
Cedar, American . . .	361	35.0625	0.32465	49.2838
Poon	379	36.1875	0.33506	47.7512
Willow	385	36.5625	0.33858	47.2613
Cedar	396	37.2500	0.34490	46.3892
Cypress	398	37.3750	0.34664	46.2841
Elm	680	37.5000	0.34722	46.0800
Pitch-pine	660	41.2500	0.38194	41.8999
Pear-tree	661	41.3125	0.38252	41.8275
Walnut	681	42.5625	0.39467	40.5991
Fir, Mar Forest . . .	694	43.3750	0.40162	39.8386
Elder-tree	695	43.4375	0.40219	39.7812
Orange-tree	705	44.0625	0.40798	39.2170
Cherry-tree	715	44.6875	0.41377	38.6685
Teak	745	46.5625	0.43113	37.1114
Fir, Riga	750	46.8750	0.43402	36.8640
Maple	755	47.1875	0.43692	36.6198
Oak, Danish	760	47.5000	0.43981	36.3789
Yew, Dutch	788	49.2500	0.45590	35.0862
Apple-tree	793	49.5625	0.45891	34.8656
Yew, Spanish	807	50.4375	0.46701	34.2602
Ash	845	52.8125	0.48000	32.7105
Beech	852	53.2500	0.48305	32.4507
Oak, Canadian	872	54.5000	0.50694	31.7061
Leywood	913	57.0625	0.53125	30.2825
Oak, English	970	60.6250	0.56184	28.5030
Box, French	1,030	64.3750	0.59006	26.8427
Brazil-wood, red . . .	1,031	64.3125	0.59064	26.8680
Mahogany, Spanish . .	1,063	66.4250	0.61516	26.0148
Oak, English, 60 yrs old	1,170	73.1250	0.67708	23.6307
Ebony, American . . .	1,331	83.4875	0.77025	20.7723
Lignum-vita	1,338	83.8125	0.77141	20.7411
LIQUIDS.				
Ether, sulphuric . . .	720	45.0000	0.41666	38.4000

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cub. Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
LIQUIDS (<i>continued</i>).				
Alcohol, absolute . . .	796	49.500	0.46034	34.718
Brandy . . .	837	52.3125	0.48437	33.982
Bisumen, liquid . . .	848	53.0000	0.49074	32.9637
Turpentine, oil of . . .	870	54.3750	0.50347	31.9638
Ether, mariatic . . .	874	54.6250	0.50578	31.7338
Olive oil . . .	915	57.1875	0.52951	30.2163
Moselle wine . . .	916	57.2500	0.53009	30.1834
Whale oil . . .	923	57.6875	0.53414	29.9548
Proof spirit . . .	930	58.1250	0.53819	29.7296
Linseed oil . . .	940	58.7500	0.54408	29.4127
Castor oil . . .	970	61.6250	0.56134	28.5031
Wine, red port . . .	990	61.8750	0.57294	27.9272
" of Burgundy . . .	991	61.9375	0.57319	27.8990
" of Bordeaux . . .	994	62.1250	0.57523	27.9118
" white Chateauagne . . .	997	62.3125	0.57696	27.7911
Water distilled . . .	1,000	62.5000	0.57870	27.6180
Tar . . .	1,000	63.4375	0.58738	27.2396
Vinegar . . .	1,026	64.1250	0.59375	26.9473
Sea-water . . .	1,028	64.2500	0.59490	26.8949
Milk . . .	1,030	64.3750	0.59600	26.8427
Air (average) . . .	1,055	64.6875	0.59895	26.7190
Blood, human . . .	1,045	63.3125	0.59474	26.4574
Muriatic acid of com- merce . . .	1,218	76.1250	0.70486	22.6993
Aqua regia . . .	1,234	77.1250	0.71412	22.4051
Water of Dead Sea . . .	1,240	77.5000	0.71759	22.2580
Nitrous acid . . .	1,452	90.7500	0.81024	19.0082
Nitric acid, ragnafortis . . .	1,500	93.7500	0.80805	18.4000
Hydrochloric acid . . .	1,830	114.3750	1.05302	15.1081
Sulphuric acid . . .	1,848	124.0000	1.06044	13.5000
Quicksilver . . .	(See Metals.)			

TABLE 88.—SPECIFIC GRAVITIES OF BODIES.

(Adopted by the Standards Department of the Board of Trade.)

	Specific Gravity.
Agate	2.6
Aluminium (rolled)	2.67
" bronze, copper 9, aluminium 1	8.0
Antimony	6.72
Arsenic	5.67
Barium	4.0
Beech	0.8
Bismuth	9.82
Bone	1.8 to 2.0
Boron	2.69
Brass	8.0
Brick, ordinary	2.17
Bromine	2.966
Bronze, copper 86.3, zinc 4.0, tin 9.7	8.45
Bronze, copper 32, zinc 2, tin 5 (Baily's)	8.4
Bronze coins, copper 95, zinc 1, tin 4	8.66
Calcium	1.58
Carbonic acid gas	1.529
Chalk	2.1
Cobalt	7.81
Copper (rolled)	8.94
Cork	0.24
Ebony	1.18
Ether, $C_2H_5O_2$	0.73
Glass, ordinary crown	2.45
" French	2.65
" flint	3.59
" crystal	3.33
Glycerine	1.27
Gold	19.32
" alloy (18 carat)	14.88
" " gold 983, copper 17	18.92
" " 11 " 1	17.49
" " 9 " 1	17.17
Granite	2.64 to 2.76
Hydrogen	0.06926
Iodine	4.95
Iridium	22.38
Iron	
" wrought	7.79

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

	Specific Gravity.
Iron, cast	7.20
Lead	11.35
Magnesium	1.74
Mahogany	0.56
Manganese	8.01
Marble	2.32 to 2.84
Mercury	13.59593
Nickel (rolled)	8.67
Nitric acid (fuming)	1.451
Nitrogen	0.97137
Oak	0.93
Oil, olive	0.91
„ sperm	0.93
„ colza	0.91
Osmium	21.40
Oxygen	1.10563
Palladium (rolled)	11.78
Palladium alloy, Matthey's Standard, silver 60%, palladium, 40%	11.00
Petroleum	0.84
Pine wood	0.56
Phosphorus	1.77
Porcelain	2.5
Platinum	21.45
„ alloy, platinum 90, iridium 10	21.57
„ „ „ 85, „ 15	21.58
„ „ „ 2, „ 1	21.62
„ „ „ 5, „ 95	22.35
Potassium	0.86
Quartz	2.65122
Rhodium	12.1
Rock crystal, <i>see</i> Quartz.	
Ruthenium	12.29
Selenium	4.30
Silver	10.51
„ alloy, silver 37, copper 3	10.38
„ „ 9 „ 1	10.31
„ „ 835 „ 165	10.20
„ „ 80 „ 20	10.06
„ „ 60 „ 40	9.80
„ „ 13 $\frac{1}{4}$ „ 2 $\frac{1}{4}$	10.17
Slate	2.41
Sodium	0.97

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

	Specific Gravity.
Steel (Whitworth's compressed)	7.796
Strontium	2.54
Sulphur	2.0
Sulphuric acid	1.848
Teak,	0.86
Thallium	11.88
Tin	7.29
Water { pure at 0°C. } { $D_{40} = 1$. . }	0.9998635
Wax	0.96
Zinc, sheet	7.19

MANUFACTURED METALS.

Tables of Weights of Manufactured Metals.

The following tables are for the most part calculated for the ordinary dimensions manufactured by the trades.

The units of specific gravity and weights adopted in the calculations of these tables, excepting where otherwise stated, are as follows:—

METALS.	Specific Gravity.	Weight of One Cubic Foot.	Weight of One Cubic Inch.
	Water = 1.000.	Pounds.	Pound.
Wrought Iron	7.698	480	.2778
Steel	7.858	490	.2836
Cast Iron	7.217	450	.2604
Lead	11.355	708	.4097
Copper	8.8917	554.4	.3208
Brass (70 copper, 30 zinc)	8.558	533.6	.3088
„ (2 „ 1 „)	8.508	530.5	.3070

The values above given for copper and brass are the results of very careful investigations made by the Broughton Copper Company.

The weights of other metals may be calculated by means of suitable multipliers from the weights of any given metal. Taking the weights of wrought-iron, copper, and the brass successively as 1, the respective multipliers for the weights of the other metals are as follows.

METAL	Wrought Iron	Copper	Brass (70 C and 30 Z.) = 1
Wrought Iron	1.000	.8018	.8095
Steel	1.0208	.8837	.9182
Cast Iron . . . . .	.9875	.8117	.8438
Lead	1.4750	1.2771	1.3269
Copper	1.1550	1.0000	1.0388
Brass (70 copper, 30 zinc)	1.1117	.9625	1.0000
(2 1)	1.1052	.9568	.9941

Bars or Rods, and Wire

Bars or rods are rolled to dimensions in inches and fraction of an inch, as exhibited in following Tables. Wire generally is rolled to the Imperial Gauge.

Tubes

Boiler tubes, of iron, steel, or brass, are manufactured to given external diameters. Iron or steel tubes for gas, steam, or water are manufactured to given internal diameters. Copper tubes also are ordinarily manufactured to internal diameters. The thicknesses of tubes are, for the most part, regulated on the basis of the Imperial Wire Gauge. But the old Birmingham Wire-Gauge is also, to some extent, followed.

Joists and Girders.

The dimensions, weights, and calculated loads of joists and girders, of iron and steel are given in following Tables. The calculated strengths have been verified by numerous actual tests. The factor of safety, 4 applies to the uniformly loaded joists and girders of Messrs. Measures Brothers & Co.; the factor, 3 is applied for the distributed loads of the steel joists and girders of Messrs. Dorman, Long & Co., and the breaking weight, applied at the centre, is given with the coefficients of strength in the tests of the Butterley Company.

Joists fail under loads by the breaking of the flange in compression; never by tensile stress.

The normal length of joists is 30 feet.

TABLE 89.—METALS: WEIGHTS FOR VARIOUS DIMENSIONS.

METAL.	Specific Weight.	Weight of One Cubic Foot.	Weight of One Square Foot.			Weight of One Lineal Ft. 1 In. Sq.	Weight of One Cubic Inch.
			1 Inch Thick.	$\frac{1}{4}$ Inch Thick.	$\frac{1}{8}$ Inch Thick.		
	Wrought Iron = 1.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
Aluminium, wrought	·348	167	13·92	1·74	1·39	1·160	·097
„ cast	·333	160	13·33	1·67	1·33	1·111	·092
Antimony	·879	418	34·83	4·35	3·48	2·902	·242
Bismuth	1·285	617	51·42	6·42	5·14	4·283	·357
Brass, cast	1·052	505	42·08	5·26	4·21	3·507	·292
„ sheet	1·098	527	43·92	5·49	4·39	3·652	·304
„ yellow	1·079	518	43·17	5·40	4·32	3·597	·298
„ Muntz metal.	1·062	511	42·58	5·32	4·26	3·549	·296
„ wire	1·110	533	44·42	5·55	4·44	3·701	·308
Bronze, gun-metal	1·106	531	44·25	5·54	4·43	3·688	·307
„ mill bearings	1·133	544	45·33	5·66	4·53	3·780	·315
„ small bells	1·004	482	40·17	5·04	4·02	3·347	·279
„ speculum metal	·969	465	38·75	4·84	3·88	3·299	·269
Copper, sheet	1·114	549	45·75	5·72	4·58	3·813	·318
„ hammered	1·158	556	46·33	5·79	4·63	3·861	·322
„ wire	1·154	554	46·17	5·77	4·62	3·778	·315
Gold	2·500	1200	100·00	12·50	10·00	8·333	·694
Iron, cast	·937	450	37·50	4·69	3·75	3·125	·260
„ wrought	1·000	480	40·00	5·00	4·00	3·333	·278
Lead, sheet	1·483	712	59·33	7·41	5·93	4·944	·412
Manganese	1·040	499	41·58	5·20	4·16	3·465	·289
Mercury	1·769	849	70·75	8·84	7·07	5·896	·491
Nickel, hammered	1·127	541	45·08	5·64	4·51	3·757	·313
„ cast	1·075	516	43·00	5·37	4·30	3·583	·299
Platinum	2·796	1342	111·83	13·97	11·18	9·320	·777
Silver	1·365	655	54·58	6·82	5·46	4·549	·379
Steel	1·020	490	40·83	5·12	4·10	3·403	·284
Tin	·962	462	38·50	4·81	3·85	3·208	·268
Zinc, sheet	·935	449	37·42	4·67	3·74	3·118	·260
„ cast	·892	428	35·67	4·46	3·57	2·972	·248

214 SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

TABLE 87. WEIGHT AND VOLUME OF BODIES (continued)

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.		
EARTH, STONES, &c. (continued).				
Garnet, common . . .	3,576	223 5000	2 06944	7 731
Topaz, average . . .	3,800	237 5000	2 19907	7 281
Sapphire, Oriental . .	3,994	243 3750	2 25347	7 101
Garnet, precious . . .	4,230	264 3750	2 44791	6 551
Ruby, Oriental . . .	4 283	267 0875	2 47858	6 451
Jargoon of Ceylon . . .	4,416	276 0000	2 55555	6 261
Spat. heavy . . .	4,430	276 8750	2 56365	6 241
Leadstone . . .	4,930	308 1250	2 80300	5 661
The earth (mean of the globe) . . .	5,210	325 6250	3 01504	5 861
RESINS, GUMS, &c.				
Gunpowder, loose heap	836	52 2500	0 48379	33 021
Living men . . .	891	55 6875	0 51562	31 061
Wax . . .	897	56 0625	0 51909	30 821
Ice . . .	930	58 1250	0 53819	29 731
Gunpowder, close shaken	937	58 5625	0 54224	29 501
Tallow . . .	942	58 8750	0 54513	29 351
Butter . . .	942	58 8750	0 54513	29 281
Beeswax . . .	956	59 7500	0 55324	28 921
Sodium . . .	972	60 7500	0 56250	28 441
Camphor . . .	989	61 8125	0 56655	27 951
Resin . . .	1,100	68 7000	0 63657	25 091
Pitch . . .	1 150	71 8750	0 66550	24 041
Opium . . .	1 337	83 5625	0 77372	20 871
Gum Arabic . . .	1 452	90 7500	0 84027	19 041
Honey . . .	1,456	91 0000	0 84259	18 981
Bone, of an ox . . .	1,659	103 6875	0 96006	16 661
.. dry . . .	1,660	103 7500	0 96064	16 651
Phosphorus . . .	1,714	107 1250	0 99184	16 131
Alum . . .	1,714	107 1250	0 99184	16 131
Gunpowder solid . . .	1,745	109 0625	1 00283	15 841
Nitre (saltpetre) . . .	1,900	118 7500	1 09953	14 551
Ivory . . .	1,917	119 8125	1 10987	14 411
WOODS.				
Cork . . .	240	15 0000	0 13888	11 521

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
WOODS (<i>continued</i>).				
Poplar	383	23.9375	0.22164	71.7660
Larch	544	34.0000	0.31481	50.8235
Fir, North of England	556	34.7500	0.32175	49.7268
Mahogany, Honduras .	560	35.0000	0.32407	49.3714
Cedar, American . . .	561	35.0625	0.32465	49.2833
Poon	579	36.1875	0.33506	47.7512
Willow	585	36.5625	0.35858	47.2015
Cedar	596	37.2500	0.34490	46.3892
Cypress	598	37.3750	0.34664	46.2341
Elm	600	37.5000	0.34722	46.0800
Pitch-pine	660	41.2500	0.38194	41.8099
Pear-tree	661	41.3125	0.38252	41.8275
Walnut	681	42.5625	0.39467	40.5991
Fir, Mar Forest . . .	694	43.3750	0.40162	39.8386
Elder-tree	695	43.4375	0.40219	39.7812
Orange-tree	705	44.0625	0.40798	39.2170
Cherry-tree	715	44.6875	0.41377	38.6685
Teak	745	46.5625	0.43113	37.1114
Fir, Riga	750	46.8750	0.43402	36.8649
Maple	755	47.1875	0.43692	36.6198
Oak, Dantzic	760	47.5000	0.43981	36.3789
Yew, Dutch	788	49.2500	0.45590	35.0862
Apple-tree	798	49.8625	0.45891	34.8658
Yew, Spanish	807	50.4375	0.46701	34.2602
Ash	845	52.8125	0.48000	33.7105
Beech	852	53.2500	0.49305	32.4507
Oak, Canadian	872	54.5000	0.50694	31.7064
Logwood	913	57.0625	0.53125	30.2825
Oak, English	970	60.6250	0.56134	28.5080
Box, French	1,030	64.3750	0.59606	26.8427
Brazil-wood, red . . .	1,031	64.3125	0.59664	26.8680
Mahogany, Spanish . .	1,063	66.4250	0.61516	26.0143
Oak, English, 60 yrs old	1,170	73.1250	0.67708	23.6307
Ebony, American . . .	1,331	83.1875	0.77025	20.7723
Lignum-vitæ	1,333	83.3125	0.77141	20.7411

LIQUIDS.

<i>Ether, sulphuric</i> . . .	720	45.0000	0.41666	38.4
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TABLE 87. WEIGHT AND VOLUME OF BODIES (continued).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cub. Inch in One Pound.
	Oz.	Lb.	Oz.	Cub. Inch.
LIQUIDS (continued).				
Alcohol, absolute . . .	796	49.7500	0.46064	34.74
Brandy . . .	837	52.3125	0.48437	33.05
Bitumen, liquid . . .	848	53.0000	0.49074	32.00
Turpentine, oil of . . .	850	54.3750	0.50347	31.96
Ether, muriatic . . .	874	54.6250	0.50578	31.63
Olive oil . . .	915	57.1875	0.52951	30.21
Moselle wine . . .	916	57.2500	0.53009	30.18
Whale oil . . .	923	57.6875	0.53411	29.95
Proof spirit . . .	930	58.1250	0.53819	29.72
Linseed oil . . .	940	58.7500	0.54308	29.41
Castor oil . . .	940	58.6250	0.54134	28.50
Wine, red port . . .	990	61.8750	0.57291	27.92
" of Burgundy . . .	991	61.9375	0.57319	27.89
" of Bordeaux . . .	994	62.1250	0.57528	27.81
" white Champagne . . .	997	62.3125	0.57696	27.73
Water, distilled . . .	1,000	62.5000	0.57870	27.64
Tar . . .	1,015	63.4375	0.58738	27.25
Vinegar . . .	1,026	64.1250	0.59375	26.94
Sea-water . . .	1,028	64.2500	0.59490	26.89
Milk . . .	1,030	64.3750	0.59606	26.84
Air (average) . . .	1,037	64.5875	0.59835	26.71
Body human . . .	1,045	65.3125	0.60474	26.43
Muriatic acid of commerce . . .	1,218	76.1250	0.70486	22.69
Aqua regia . . .	1,234	77.1250	0.71412	22.40
Water of Dead Sea . . .	1,240	77.5000	0.71759	22.25
Nitrous acid . . .	1,472	90.7500	0.84024	19.00
Nitric acid, aquafortis . . .	1,500	93.7500	0.86805	18.40
Boric acid . . .	1,810	114.3750	1.05902	15.16
Sulphuric acid . . .	1,848	128.0000	1.06941	13.70
Quicksilver . . .	(See Metals.)			

TABLE 88.—SPECIFIC GRAVITIES OF BODIES.

(Adopted by the Standards Department of the Board of Trade.)

	Specific Gravity.
Agate	2.6
Aluminium (rolled)	2.67
" bronze, copper 9, aluminium 1	8.0
Antimony	6.72
Arsenic	5.67
Barium	4.0
Beech	0.8
Bismuth	9.82
Bone	1.8 to 2.0
Boron	2.69
Brass	8.0
Brick, ordinary	2.17
Bromine	2.966
Bronze, copper 86.3, zinc 4.0, tin 9.7	8.45
Bronze, copper 32, zinc 2, tin 5 (Baily's)	8.4
Bronze coins, copper 95, zinc 1, tin 4	8.66
Calcium	1.58
Carbonic acid gas	1.529
Chalk	2.1
Cobalt	7.81
Copper (rolled)	8.94
Cork	0.24
Ebony	1.18
Ether, $C_2H_{10}O_2$	0.73
Glass, ordinary crown	2.45
" French	2.65
" flint	3.59
" crystal	3.33
Glycerine	1.27
Gold	19.32
" alloy (18 carat)	14.88
" " gold 983, copper 17	18.92
" " 11 " 1	17.49
" " 9 " 1	17.17
Granite	2.64 to 2.76
Hydrogen	0.06926
Iodine	4.95
Iridium	22.38
Iron	
" wrought	7.79

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

	Specific Gravity.
Iron, cast	7.20
Lead	11.35
Magnesium	1.74
Mahogany	0.56
Manganese	8.01
Marble	2.52 to 2.84
Mercury	13.59593
Nickel (rolled)	8.67
Nitric acid (fuming)	1.451
Nitrogen	0.97137
Oak	0.93
Oil, olive	0.91
„ sperm	0.93
„ colza	0.91
Osmium	21.40
Oxygen	1.10563
Palladium (rolled)	11.78
Palladium alloy, Matthey's Standard, silver 60%, palladium, 40%	11.00
Petroleum	0.84
Pine wood	0.56
Phosphorus	1.77
Porcelain	2.5
Platinum	21.43
„ alloy, platinum 90, iridium 10	21.57
„ „ „ 85, „ 15	21.58
„ „ „ 2, „ 1	21.62
„ „ „ 5, „ 95	22.35
Potassium	0.86
Quartz	2.65122
Rhodium	12.1
Rock crystal, <i>see</i> Quartz.	
Ruthenium	12.29
Selenium	4.30
Silver	10.51
„ alloy, silver 37, copper 3	10.38
„ „ 9 „ 1	10.31
„ „ 835 „ 165	10.20
„ „ 80 „ 20	10.06
„ „ 60 „ 40	9.80
„ „ 134 „ 24	10.17
Slate	2.11
Sodium	0.97

TABLE 88.—SPECIFIC GRAVITIES OF BODIES.

(Adopted by the Standards Department of the Board of Trade.)

	Specific Gravity.
Agate	2.6
Aluminium (rolled)	2.67
bronze, copper 9, aluminium 1	8.0
Antimony	6.72
Arsenic	5.67
Barium	4.0
Beech	0.8
Bismuth	9.82
Bone	1.8 to 2.0
Boron	2.69
Brass	8.0
Brick, ordinary	2.17
Bromine	2.966
Bronze, copper 86.3, zinc 4.0, tin 9.7	8.45
Bronze, copper 32, zinc 2, tin 5 (Baily's)	8.4
Bronze coins, copper 95, zinc 1, tin 4	8.66
Calcium	1.58
Carbonic acid gas	1.529
Chalk	2.1
Cobalt	7.81
Copper (rolled)	8.94
Cork	0.24
Ebony	1.18
Ether, $C_2H_5O_2$	0.73
Glass, ordinary crown	2.45
" French	2.65
" flint	3.59
" crystal	3.33
Glycerine	1.27
Gold	19.32
" alloy (18 carat)	14.88
" " gold 983, copper 17	18.92
" " 11 " 1	17.49
" " 9 " 1	17.17
Granite	2.64 to 2.76
Hydrogen	0.06926
Iodine	4.95
Iridium	22.38
Iron	
" wrought	7.79

The weights of other metals may be calculated by means of suitable multipliers from the weights of any given metal. Taking the weights of wrought-iron, copper, and the brass successively as 1, the respective multipliers for the weights of the other metals are as follows.

METAL	Wrought Iron	Copper	Brass (70 C and 30 Z) = 1.
Wrought Iron	1.000	.8618	.8105
Steel	1.0208	.8837	.9182
Cast Iron . . . . .	.9375	.8117	.8438
Lead	1.4750	1.2771	1.3269
Copper	1.1550	1.0000	1.0388
Brass (70 copper, 30 zinc)	1.1117	.9625	1.0000
(2 1)	1.1052	.9568	.9941

Bars or Rods, and Wire.

Bars or rods are rolled to dimensions in inches and fractions of an inch, as exhibited in following Tables. Wire generally is rolled to the Imperial Gauge.

Tubes.

Boiler tubes, of iron, steel, or brass, are manufactured to given external diameters. Iron or steel tubes for gas, steam, or water, are manufactured to given internal diameters. Copper tubes also are ordinarily manufactured to internal diameters. The thicknesses of tubes are, for the most part, regulated on the basis of the Imperial Wire Gauge. But the old Birmingham Wire Gauge is also, to some extent, followed.

Joists and Girders

The dimensions, weights, and calculated loads of joists and girders, of iron and steel, are given in following tables. The calculated strengths have been verified by numerous actual tests. The factor of safety, 4, applies to the uniformly loaded joists and girders of Messrs. Messers Brothers & Co., the factor 3 is applied for the distributed loads of the steel joists and girders of Messrs. Dorman, Long & Co., and the breaking weight, applied at the centre, is given with the coefficients of stress, 1, in the joints of the latter company.

Joists fail under loads by the breaking of the flange in compression, never by tensile stress.

The normal length of joists is 30 feet.

TABLE 88. SPECIFIC GRAVITIES OF BODIES (continued).

	Specific Gravity.
Steel (Whitworth's compressed)	7.796
Strontium	2.54
Sulphur	2.0
Sulphuric acid	1.848
Tank	0.86
Thallium	11.88
Tin	7.29
Water : pure at 0° C. ()	0.9998635
($D_{20} = 1$. . .)	
Wax	0.96
Zinc, sheet	7.19

MANUFACTURED METALS.

Tables of Weights of Manufactured Metals.

The following tables are for the most part calculated for the ordinary dimensions manufactured by the trades.

The units of specific gravity and weights adopted in the calculations of these tables, excepting when otherwise stated, are as follows:

METALS.	Specific Gravity	Weight of Weight of the Cube One Cubic Foot. 1 foot	
		Feet.	Feet.
	Water 100	1000 lbs.	1000 lbs.
Wrought Iron	7.698	480	2778
Steel	7.858	490	2836
Cast Iron	7.217	450	2604
Lead	11.355	708	4097
Copper	8.891	554.4	3208
Brass (70 copper, 30 zinc)	8.558	533.6	3088
.. (2 .. 1 ..)	8.508	530.5	3070

The values above given for copper and brass are the results of very careful investigations made by the Broughton Copper

Company.

TABLE 90. WEIGHTS OF FLAT BAR IRON.

Length 1 Foot.

Thick- ness.	Width in Inches.								
	$\frac{1}{2}$	$\frac{3}{4}$	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	2	2 $\frac{1}{4}$	2 $\frac{1}{2}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	2.08	2.60	3.12	3.65	4.17	4.69	5.21	5.73	6.25
$\frac{1}{16}$	3.12	3.91	4.69	5.47	6.25	7.03	7.81	8.59	9.37
$\frac{1}{32}$	4.17	5.21	6.25	7.29	8.33	9.38	1.04	1.15	1.25
$\frac{1}{64}$	5.21	6.51	7.81	9.11	1.04	1.17	1.30	1.43	1.56
$\frac{1}{128}$	6.25	7.81	9.37	1.09	1.25	1.41	1.56	1.72	1.88
$\frac{1}{256}$	7.29	9.11	1.09	1.28	1.46	1.64	1.82	2.01	2.19
$\frac{1}{512}$	8.33	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50
$\frac{1}{1024}$	9.37	1.17	1.41	1.64	1.88	2.11	2.34	2.58	2.81
$\frac{1}{2048}$	1.04	1.30	1.56	1.82	2.08	2.34	2.60	2.86	3.13
$\frac{1}{4096}$	1.15	1.43	1.72	2.01	2.29	2.58	2.86	3.15	3.44
$\frac{1}{8192}$	1.25	1.56	1.87	2.19	2.50	2.81	3.13	3.44	3.75
$\frac{1}{16384}$	1.35	1.69	2.03	2.37	2.71	3.05	3.39	3.72	4.06
$\frac{1}{32768}$	1.46	1.82	2.19	2.55	2.92	3.28	3.65	4.01	4.38
$\frac{1}{65536}$	1.56	1.95	2.34	2.73	3.13	3.52	3.91	4.30	4.69
1	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00

Thick- ness.	Width in Inches.								
	1 $\frac{5}{8}$	1 $\frac{7}{8}$	2 $\frac{1}{8}$	2	2 $\frac{1}{4}$	2 $\frac{1}{2}$	2 $\frac{3}{4}$	3	3 $\frac{1}{4}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	6.77	7.29	7.81	8.33	...	...	...	...	...
$\frac{1}{16}$	1.02	1.09	1.17	1.25	1.33	1.41	1.48	1.56	1.64
$\frac{1}{32}$	1.47	1.46	1.56	1.67	1.77	1.88	1.98	2.08	2.19
$\frac{1}{64}$	1.69	1.82	1.95	2.08	2.21	2.34	2.47	2.60	2.73
$\frac{1}{128}$	2.03	2.19	2.34	2.50	2.66	2.81	2.97	3.13	3.28
$\frac{1}{256}$	2.87	2.57	2.73	2.92	3.10	3.28	3.46	3.65	3.83
$\frac{1}{512}$	2.71	2.92	3.13	3.33	3.54	3.75	3.96	4.17	4.38
$\frac{1}{1024}$	3.05	3.28	3.52	3.75	3.98	4.22	4.45	4.69	4.92
$\frac{1}{2048}$	3.39	3.65	3.91	4.17	4.43	4.69	4.95	5.21	5.47
$\frac{1}{4096}$	3.72	4.01	4.30	4.58	4.87	5.16	5.44	5.73	6.02
$\frac{1}{8192}$	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56
$\frac{1}{16384}$	4.40	4.74	5.08	5.42	5.76	6.09	6.43	6.77	7.11
$\frac{1}{32768}$	4.74	5.10	5.47	5.83	6.20	6.56	6.93	7.29	7.66
$\frac{1}{65536}$	5.08	5.47	5.86	6.25	6.64	7.03	7.42	7.81	8.20
1	5.42	5.83	6.25	6.67	7.08	7.50	7.92	8.33	8.75

TABLE 90.—WEIGHTS OF FLAT BAR IRON (*continued*).

Thick- ness.	Width in Inches.									
	2½	3	3½	3½	3½	4	4½	4½	4½	5
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	1.80	1.88	2.03	2.11	2.20	2.33	2.44	2.55	2.66	2.77
1½	2.40	2.50	2.71	2.82	2.93	3.13	3.33	3.54	3.75	3.96
2	3.00	3.13	3.39	3.55	3.71	3.91	4.17	4.43	4.69	4.95
2½	3.59	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25
3	4.19	4.38	4.74	5.10	5.47	5.83	6.20	6.56	6.93	7.29
3½	4.79	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.92	8.33
4	5.39	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.91	9.38
4½	6.00	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.90	10.4
5	6.59	6.88	7.45	8.02	8.59	9.17	9.74	10.3	10.9	11.5
5½	7.19	7.50	8.13	8.75	9.38	10.0	10.6	11.3	11.9	12.5
6	7.79	8.13	8.80	9.48	10.2	10.8	11.5	12.2	12.9	13.5
6½	8.39	8.75	9.48	10.2	10.9	11.7	12.4	13.1	13.9	14.6
7	8.98	9.38	10.2	10.9	11.7	12.5	13.3	14.1	14.8	15.6
7½	9.58	10.0	10.8	11.7	12.5	13.3	14.2	15.0	15.8	16.7
Thick- ness.	Width in Inches.									
	5½	6	6½	7	8	9	10	11	12	
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	4.58	5.00	5.42	5.83	6.67	7.50	8.33	9.17	10.0	
1½	5.78	6.25	6.77	7.29	8.33	9.38	10.4	11.5	12.5	
2	6.88	7.50	8.13	8.75	10.0	11.3	12.5	13.8	15.0	
2½	8.02	8.75	9.47	10.2	11.7	13.1	14.6	16.0	17.5	
3	9.17	10.0	10.8	11.7	13.3	15.0	16.7	18.3	20.0	
3½	10.3	11.3	12.2	13.1	15.0	16.7	18.8	20.6	22.5	
4	11.5	12.5	13.5	14.6	16.7	18.8	20.8	22.9	25.0	
4½	12.6	13.8	14.9	16.0	18.3	20.6	22.9	25.2	27.5	
5	13.8	15.0	16.3	17.5	20.0	22.5	25.0	27.5	30.0	
5½	14.9	16.3	17.6	19.0	21.7	24.4	27.1	29.8	32.5	
6	16.0	17.5	19.0	20.1	23.3	26.3	29.2	32.1	35.0	
6½	17.2	18.8	20.3	21.9	25.0	28.1	31.3	34.4	37.5	
7	18.3	20.0	21.7	23.3	26.7	30.0	33.3	36.7	40.0	

135 by 3 to 45, 140 by 3 to 40, 150 by 3 to 45, 160 by 3 to 45, 165 by 3 to 45, 180 by 3 to 45, 210 by 8 to 45, 250 by 7 to 40, 300 by 8 to 40, 355 by 8 to 10, 400 by 8 to 10, 450 by 8 to 4 millimetres thick.

TABLE 93. -WROUGHT IRON: WEIGHT OF ONE SQUARE FOOT FOR ALL THICKNESSES OF THE IMPERIAL WEIGHT GAUGE (Standards Department).

Specific Gravity. 7 80.

I. W. G. Gauge Number	Thickness.	Weight per Square Foot.	I. W. G. Gauge Number	Thickness.	Weight per Square Foot.
No.	Inch.	Pounds.	No.	Inch.	Pounds.
7/0	·300	20·254	23	·024	·972
6 0	·464	18·796	24	·022	·891
5 0	·432	17·500	25	·020	·810
4/0	·400	16·203	26	·018	·729
3 0	·372	15·069	27	·0164	·664
2/0	·348	14·097	28	·0148	·600
0	·324	13·125	29	·0136	·551
1	·300	12·153	30	·0124	·502
2	·276	11·180	31	·0116	·470
3	·252	10·208	32	·0108	·437
4	·232	9·398	33	·0100	·405
5	·212	8·588	34	·0092	·373
6	·192	7·778	35	·0084	·340
7	·176	7·180	36	·0076	·308
8	·160	6·481	37	·0068	·275
9	·144	5·833	38	·0060	·243
10	·128	5·185	39	·0052	·211
11	·116	4·699	40	·0048	·194
12	·104	4·213	41	·0044	·178
13	·092	3·727	42	·0040	·162
14	·080	3·241	43	·0036	·146
15	·072	2·917	44	·0032	·130
16	·064	2·593	45	·0028	·113
17	·056	2·268	46	·0024	·097
18	·048	1·944	47	·0020	·081
19	·040	1·620	48	·0016	·065
20	·036	1·458	49	·0012	·049
21	·032	1·296	50	·0010	·041
22	·028	1·134			

TABLE 94.—ANGLE IRONS AND TEE IRONS : WEIGHT.
Length, 1 Foot.

Average Thick- ness.	Sum of the Width and Depth in Inches.							
	2	2 $\frac{1}{4}$	2 $\frac{1}{2}$	2 $\frac{3}{4}$	3	3 $\frac{1}{4}$	3 $\frac{1}{2}$	3 $\frac{3}{4}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	·78	·88	·99	1·09	1·20	1·30	1·41	1·51
$\frac{3}{16}$	1·13	1·29	1·45	1·60	1·76	1·91	2·07	2·23
$\frac{1}{4}$	1·46	1·67	1·88	2·08	2·29	2·50	2·71	2·92
$\frac{5}{16}$	1·76	2·02	2·28	2·54	2·80	3·06	3·32	3·58
$\frac{3}{8}$	...	...	...	...	3·28	3·59	3·91	4·22
$\frac{7}{16}$	...	...	...	...	...	...	4·48	4·84

Average Thick- ness.	Sum of the Width and Depth in Inches.							
	4	4 $\frac{1}{4}$	4 $\frac{1}{2}$	4 $\frac{3}{4}$	5	5 $\frac{1}{4}$	5 $\frac{1}{2}$	5 $\frac{3}{4}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{3}{16}$	2·38	2·54	2·70	2·85	3·01	3·16	3·32	3·48
$\frac{1}{4}$	3·13	3·33	3·54	3·75	3·96	4·17	4·38	4·58
$\frac{5}{16}$	3·84	4·10	4·36	4·62	4·88	5·14	5·40	5·66
$\frac{3}{8}$	4·53	4·84	5·16	5·47	5·78	6·09	6·41	6·72
$\frac{7}{16}$	5·20	5·56	5·92	6·29	6·65	7·02	7·38	7·75
$\frac{1}{2}$	...	...	6·67	7·08	7·50	7·92	8·33	8·75
$\frac{9}{16}$	...	...	7·38	7·85	8·32	8·79	9·26	9·73
$\frac{5}{8}$	...	...	...	8·59	9·11	9·63	10·16	10·68
$\frac{11}{16}$	...	...	...	...	10·03	10·62	11·20	11·78
$\frac{3}{4}$	...	...	...	...	...	...	...	12·50

Average Thick- ness.	Sum of the Width and Depth in Inches.							
	6	6 $\frac{1}{2}$	7	7 $\frac{1}{2}$	8	8 $\frac{1}{2}$	9	9 $\frac{1}{2}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{4}$	4·79	5·21	5·63	6·04	6·46	6·88	7·29	7·71
$\frac{5}{16}$	5·92	6·45	6·97	7·49	8·01	8·53	9·05	9·57
$\frac{3}{8}$	7·03	7·66	8·28	8·91	9·53	10·16	10·78	11·41
$\frac{7}{16}$	8·11	8·84	9·57	10·30	11·03	11·76	12·49	13·22
$\frac{1}{2}$	9·17	10·00	10·83	11·67	12·50	13·33	14·17	15·00
$\frac{9}{16}$	10·20	11·13	12·07	13·01	13·94	14·88	15·82	16·76
$\frac{5}{8}$	11·19	12·24	13·28	14·32	15·36	16·41	17·45	18·49
$\frac{11}{16}$	12·37	13·54	14·70	15·87	17·03	18·20	19·36	20·53
$\frac{3}{4}$	13·13	14·38	15·63	16·88	18·13	19·38	20·63	21·88
$\frac{7}{8}$	14·95	16·41	17·86	19·32	20·78	22·24	23·70	25·16
1	...	...	...	21·67	23·33	25·00	26·67	28·33

TABLE 94. ANGLE IRONS AND TEE IRONS: WEIGHT
(continued).

Average Thickness	Sum of the Width and Depth in Inches							
	10	10½	11	12	13	14	15	16
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{3}{8}$	12.03	12.66	13.28	14.53	1			
$\frac{7}{16}$	13.95	14.67	15.40	16.86	18.31	19.77	21.22	22.67
$\frac{1}{2}$	15.83	16.67	17.50	19.17	20.84	22.50	24.17	25.84
$\frac{9}{16}$	17.70	18.63	19.57	21.44	23.31	25.19	27.06	28.93
$\frac{5}{8}$	19.58	20.57	21.61	23.70	25.78	27.87	29.95	32.03
$\frac{3}{4}$	21.69	22.86	24.03	26.36	28.70	31.03	33.36	35.70
$\frac{7}{8}$	23.13	24.38	25.63	28.13	30.63	33.13	35.63	38.13
$\frac{15}{16}$	26.61	28.07	29.53	32.45	35.36	38.28	41.19	44.12
1	30.00	31.67	33.333	36.67	40.00	43.30	46.67	50.00

TABLE 95. WEIGHT OF FLAT BAR STEEL.

Length, 1 Foot.

Thickness	Width									
	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{16}$	213	266	319	372	425	478	532	584	637	689
$\frac{3}{16}$	320	399	478	558	638	717	797	877	956	1035
$\frac{1}{4}$	425	532	638	744	851	956	1066	1177	1288	1398
$\frac{5}{16}$	532	660	797	930	1066	1203	1333	1466	1598	1730
$\frac{3}{8}$	638	797	956	1111	1268	1423	1579	1735	1891	2047
$\frac{7}{16}$	744	930	1112	1300	1489	1677	1866	2055	2243	2432
$\frac{1}{2}$	851	1066	1288	1499	1709	1911	2113	2314	2515	2716
$\frac{9}{16}$	957	1203	1443	1677	1911	2145	2379	2613	2847	3081
$\frac{5}{8}$	1066	1333	1599	1866	2133	2399	2666	2933	3200	3467
$\frac{3}{4}$	1177	1466	1755	2055	2344	2633	2922	3211	3500	3789
$\frac{7}{8}$	1288	1599	1911	2223	2535	2847	3159	3471	3783	4095
$\frac{15}{16}$	1398	1730	2077	2442	2776	3111	3445	3779	4113	4447
$\frac{15}{16}$	1499	1866	2223	2600	2938	3275	3612	3949	4286	4623
1	1599	1999	2399	2799	3199	3599	3999	4399	4799	5199
1	1700	2133	2565	2998	3430	3863	4295	4728	5160	5593

TABLE 85.—WEIGHT OF FLAT BAR STEEL. (continued).

Thick- ness.	Width									
	1½	1¾	1½	2	2½	2½	3	3½	4	4½
Inch	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	1.01	1.11	1.22	1.33	1.44	1.55	1.66	1.77	1.88	1.99
3/16	1.04	1.14	1.25	1.36	1.47	1.58	1.69	1.80	1.91	2.02
1/4	1.38	1.49	1.59	1.70	1.81	1.91	2.02	2.13	2.23	2.34
5/16	1.73	1.84	1.95	2.05	2.16	2.26	2.37	2.47	2.58	2.68
3/8	2.07	2.23	2.39	2.55	2.71	2.87	3.03	3.19	3.35	3.51
7/16	2.42	2.60	2.76	2.92	3.08	3.24	3.40	3.56	3.72	3.88
1/2	2.76	2.98	3.19	3.41	3.62	3.83	4.04	4.25	4.46	4.68
5/8	3.11	3.35	3.59	3.83	4.07	4.31	4.54	4.78	5.02	5.26
3/4	3.45	3.72	3.99	4.25	4.52	4.78	5.05	5.31	5.58	5.84
7/8	3.80	4.09	4.39	4.68	4.97	5.26	5.55	5.84	6.14	6.43
1	4.14	4.46	4.78	5.10	5.42	5.74	6.06	6.38	6.69	7.01
1 1/8	4.49	4.84	5.18	5.53	5.87	6.22	6.57	6.92	7.26	7.60
1 1/4	4.83	5.21	5.58	5.96	6.33	6.70	7.07	7.44	7.81	8.18
1 3/8	5.18	5.58	5.98	6.38	6.78	7.18	7.58	7.98	8.37	8.77
1 1/2	5.53	5.96	6.38	6.81	7.23	7.66	8.08	8.51	8.93	9.36

Thick- ness.	Width									
	2½	3	3½	4	4½	5	5½	6	6½	7
Inch	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	1.22	1.38	1.54	1.70	1.86	2.02	2.18	2.34	2.50	2.66
3/16	1.84	1.91	2.07	2.23	2.39	2.55	2.71	2.87	3.03	3.19
1/4	2.44	2.55	2.76	2.98	3.19	3.40	3.61	3.83	4.04	4.25
5/16	3.06	3.19	3.41	3.72	3.98	4.25	4.51	4.78	5.05	5.32
3/8	3.67	3.83	4.14	4.46	4.78	5.10	5.42	5.74	6.06	6.38
7/16	4.28	4.44	4.83	5.21	5.58	5.95	6.32	6.70	7.07	7.44
1/2	4.89	5.10	5.53	5.96	6.38	6.80	7.23	7.66	8.08	8.50
5/8	5.50	5.74	6.21	6.70	7.18	7.66	8.14	8.61	9.09	9.57
3/4	6.11	6.38	6.91	7.44	7.97	8.50	9.04	9.57	10.10	10.63
7/8	6.72	7.02	7.60	8.19	8.78	9.36	9.94	10.52	11.11	11.70
1	7.33	7.65	8.29	8.93	9.56	10.20	10.85	11.48	12.12	12.76
1 1/8	7.95	8.29	8.98	9.68	10.37	11.06	11.75	12.44	13.13	13.82
1 1/4	8.55	8.93	9.67	10.41	11.16	11.90	12.65	13.40	14.14	14.89
1 3/8	9.17	9.57	10.37	11.16	11.96	12.76	13.56	14.35	15.15	15.95
1 1/2	9.78	10.21	11.06	11.91	12.76	13.68	14.46	15.31	16.16	17.01

135 by 3 to 45, 140 by 3 to 40, 150 by 3 to 45, 160 by 3 to 45, 165 by 3 to 45, 180 by 3 to 45, 210 by 8 to 45, 230 by 7 to 40, 300 by 8 to 40, 355 by 8 to 40, 400 by 8 to 40, 450 by 8 to 40 millimetres thick.

TABLE 93.—WROUGHT IRON: WEIGHT OF ONE SQUARE FOOT FOR ALL THICKNESSES OF THE IMPERIAL WIRE GAUGE (Standards Department).

Specific Gravity, 7·80.

I. W. G. Gauge Number	Thickness.	Weight per Square Foot.	I. W. G. Gauge Number	Thickness.	Weight per Square Foot.
No.	Inch.	Pounds.	No.	Inch.	Pounds.
7/0	·300	20·254	23	·024	·972
6/0	·464	18·796	24	·022	·891
5/0	·432	17·500	25	·020	·810
4/0	·400	16·208	26	·018	·729
3/0	·372	15·009	27	·0164	·664
2/0	·348	14·097	28	·0148	·600
0	·324	13·125	29	·0136	·551
1	·300	12·153	30	·0124	·502
2	·276	11·180	31	·0116	·470
3	·252	10·208	32	·0108	·437
4	·232	9·398	33	·0100	·405
5	·212	8·588	34	·0092	·373
6	·192	7·778	35	·0084	·340
7	·176	7·130	36	·0076	·308
8	·160	6·481	37	·0068	·275
9	·144	5·833	38	·0060	·243
10	·128	5·185	39	·0052	·211
11	·116	4·699	40	·0048	·194
12	·104	4·213	41	·0044	·178
13	·092	3·727	42	·0040	·162
14	·080	3·241	43	·0036	·146
15	·072	2·917	44	·0032	·130
16	·064	2·593	45	·0028	·113
17	·056	2·268	46	·0024	·097
18	·048	1·944	47	·0020	·081
19	·040	1·620	48	·0016	·065
20	·036	1·458	49	·0012	·049
21	·032	1·296	50	·0010	·041
22	·028	1·134			

TABLE 94. ANGLE IRONS AND TEE IRONS. WEIGHT
Length, 1 Foot

Average Thick- ness	Sum of the Width and Depth in Inches.							
	2	2½	2½	2½	3	3½	3½	3½
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	.78	.88	.99	1.09	1.20	1.30	1.41	1.51
1½	1.13	1.29	1.45	1.60	1.76	1.91	2.07	2.23
2	1.46	1.67	1.88	2.08	2.29	2.50	2.71	2.92
2½	1.76	2.02	2.28	2.54	2.80	3.06	3.32	3.58
3	...	...	...	...	3.28	3.59	3.91	4.22
3½	...	...	...	...	...	...	4.48	4.84

Average Thick- ness	Sum of the Width and Depth in Inches							
	4	4½	4½	4½	5	5½	5½	5½
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3½	2.38	2.54	2.70	2.85	3.01	3.16	3.32	3.48
4	3.13	3.33	3.54	3.75	3.96	4.17	4.38	4.58
4½	3.84	4.10	4.36	4.62	4.88	5.14	5.40	5.66
5	4.53	4.84	5.16	5.47	5.78	6.09	6.41	6.72
5½	5.20	5.56	5.92	6.29	6.65	7.02	7.38	7.75
6	...	...	6.67	7.08	7.50	7.92	8.33	8.75
6½	...	...	7.38	7.85	8.32	8.79	9.26	9.73
7	...	...	...	8.59	9.11	9.63	10.16	10.68
7½	...	...	...	...	10.03	10.62	11.20	11.78
8	...	...	...	...	...	...	...	12.50

Average Thick- ness	Sum of the Width and Depth in Inches.							
	6	6½	6½	7½	8	8½	9	9½
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	4.79	5.21	5.63	6.04	6.46	6.88	7.29	7.71
6½	5.92	6.40	6.87	7.49	8.01	8.53	9.04	9.57
7	7.03	7.66	8.28	8.91	9.53	10.16	10.78	11.41
7½	8.11	8.84	9.57	10.30	11.03	11.76	12.49	13.22
8	9.17	10.00	10.83	11.67	12.50	13.33	14.17	15.00
8½	10.24	11.13	12.07	13.01	13.94	14.88	15.82	16.76
9	11.19	12.24	13.28	14.32	15.36	16.41	17.45	18.49
9½	12.37	13.54	14.70	15.87	17.03	18.20	19.36	20.53
10	13.43	14.78	16.03	17.28	18.53	19.78	21.03	22.28
10½	14.55	16.11	17.36	18.62	20.78	22.24	23.70	25.16
11	...	...	...	21.67	23.33	25.00	26.67	28.33

TABLE 94. ANGLE IRONS AND TEE IRONS. WEIGHT
(continued).

Average Thickness in ins.	Sum of the Width and Depth in Inches							
	10	10½	11	12	13	14	15	16
Inch	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{3}{8}$	12.03	12.46	13.28	14.53				
$\frac{7}{16}$	13.95	14.67	15.40	16.86	18.31	19.77	21.22	22.67
$\frac{1}{2}$	15.83	16.67	17.50	19.17	20.84	22.50	24.17	25.84
$\frac{9}{16}$	17.70	18.63	19.57	21.44	23.31	25.19	27.06	28.98
$\frac{5}{8}$	19.53	20.57	21.61	23.70	25.78	27.87	29.95	32.03
$\frac{3}{4}$	21.69	22.86	24.03	26.36	28.70	31.03	33.36	35.70
$\frac{7}{8}$	23.13	24.38	25.63	28.13	30.63	33.13	35.63	38.13
$\frac{15}{16}$	26.61	28.07	29.53	32.45	35.36	38.28	41.19	44.12
1	30.00	31.67	33.33	36.67	40.00	43.30	46.67	50.00

TABLE 95. WEIGHT OF FLAT BAR STEEL.

Length, 1 Foot.

Thickness in ins.	Width								
	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1½	1¾	1½	1½
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	213	266	319	372	425	478	532	584	638
$\frac{3}{16}$	320	399	478	558	638	717	797	877	957
$\frac{1}{4}$	425	532	638	744	851	960	1066	1177	1288
$\frac{5}{16}$	532	666	797	930	1066	1203	1338	1466	1599
$\frac{3}{8}$	638	797	957	1111	1288	1466	1638	1777	1911
$\frac{7}{16}$	744	930	1111	1303	1499	1677	1866	2055	2244
$\frac{1}{2}$	851	1066	1288	1499	1711	1911	2133	2344	2555
$\frac{9}{16}$	957	1222	1466	1677	1911	2133	2366	2599	2833
$\frac{5}{8}$	1066	1338	1599	1866	2133	2399	2666	2933	3199
$\frac{11}{16}$	1177	1466	1777	2055	2344	2633	2922	3211	3500
$\frac{3}{4}$	1288	1599	1911	2222	2511	2800	3099	3388	3677
$\frac{13}{16}$	1388	1711	2055	2422	2766	3111	3455	3799	4144
$\frac{7}{8}$	1499	1866	2244	2600	2988	3377	3777	4177	4577
$\frac{15}{16}$	1599	1999	2399	2799	3199	3599	3999	4399	4799
1	1700	2133	2555	2988	3400	3833	4255	4688	5111

TABLE 95.—WEIGHT OF FLAT BAR STEEL (continued).

Thick- ness.	Width									
	1½	1¾	1⅞	2	2½	2¾	2⅞	3	3½	3¾
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
¼	691	744	797	851	904	958	1 01	1 06	1 11	1 16
⅜	1 04	1 11	1 19	1 28	1 36	1 43	1 51	1 59	1 67	1 75
½	1 38	1 49	1 59	1 70	1 81	1 91	2 02	2 13	2 23	2 34
⅝	1 73	1 85	1 99	2 13	2 26	2 39	2 52	2 66	2 79	2 92
¾	2 07	2 23	2 39	2 55	2 71	2 87	3 03	3 19	3 35	3 51
7/8	2 42	2 60	2 79	2 98	3 16	3 35	3 53	3 72	3 91	4 09
1	2 76	2 98	3 19	3 40	3 61	3 83	4 04	4 27	4 46	4 68
1 1/8	3 11	3 35	3 59	3 83	4 07	4 31	4 54	4 78	5 02	5 26
1 ¼	3 45	3 72	3 99	4 25	4 52	4 78	5 05	5 31	5 58	5 84
1 ½	3 80	4 09	4 39	4 68	4 97	5 26	5 56	5 86	6 14	6 43
1 ¾	4 14	4 46	4 78	5 10	5 42	5 74	6 06	6 38	6 69	7 01
1 ⅞	4 49	4 81	5 18	5 53	5 87	6 22	6 57	6 92	7 26	7 60
2	4 83	5 21	5 58	5 96	6 32	6 70	7 07	7 44	7 81	8 18
2 ¼	5 18	5 58	5 98	6 38	6 78	7 18	7 58	7 98	8 37	8 77
2 ½	5 53	5 96	6 38	6 81	7 23	7 66	8 08	8 51	8 93	9 36

Thick- ness.	Width									
	2½	3	3½	3¾	4	4½	4¾	5	5½	6
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
¼	1 22	1 28	1 38	1 49	1 59	1 70	...	...	...	...
⅜	1 83	1 91	2 07	2 23	2 39	2 55	...	...	...	...
½	2 44	2 54	2 70	2 98	3 19	3 40	3 61	3 83	4 04	4 25
⅝	3 06	3 19	3 45	3 72	3 98	4 24	4 51	4 78	5 05	5 32
¾	3 67	3 83	4 14	4 46	4 78	5 10	5 44	5 74	6 06	6 38
7/8	4 28	4 46	4 83	5 21	5 58	5 95	6 32	6 70	7 07	7 44
1	4 89	5 10	5 53	5 95	6 38	6 80	7 23	7 66	8 08	8 50
1 1/8	5 50	5 74	6 22	6 70	7 18	7 66	8 13	8 61	9 09	9 57
1 ¼	6 11	6 38	6 91	7 44	7 97	8 50	9 02	9 57	10 10	10 63
1 ½	6 72	7 02	7 60	8 19	8 78	9 36	9 94	10 52	11 11	11 70
1 ¾	7 33	7 64	8 29	8 93	9 56	10 20	10 83	11 48	12 12	12 76
1 ⅞	7 97	8 29	8 98	9 68	10 37	11 05	11 75	12 44	13 13	13 82
2	8 55	8 93	9 67	10 41	11 16	11 90	12 63	13 40	14 14	14 89
2 ¼	9 17	9 57	10 37	11 16	11 96	12 76	13 56	14 35	15 15	15 85
2 ½	9 78	10 21	11 06	11 91	12 76	13 68	14 46	15 31	16 16	17 00

TABLE 95. WEIGHT OF FLAT BAR STEEL (*continued*).

Thick- ness.	Width.								
	5½	6	6½	7	8	9	10	11	12
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
¼	4.68	5.10	5.53	5.95	6.80	7.66	8.51	9.36	10.21
⅕	5.84	6.38	6.91	7.44	8.50	9.57	10.63	11.70	12.76
⅙	7.02	7.66	8.29	8.93	10.20	11.48	12.76	14.04	15.31
⅚	8.19	8.93	9.68	10.42	11.90	13.59	14.89	16.37	17.86
⅞	9.36	10.21	11.06	11.91	13.60	15.31	17.01	18.71	20.42
1	10.53	11.48	12.44	13.40	15.30	17.23	19.14	21.05	22.97
1 ⅛	11.70	12.76	13.82	14.89	17.00	19.14	21.27	23.39	25.52
1 ¼	12.87	14.04	15.20	16.37	18.70	21.05	23.39	25.73	28.07
1 ⅓	14.04	15.31	16.59	17.86	20.40	22.97	25.32	28.07	30.63
1 ½	15.21	16.59	17.97	19.35	22.10	24.88	27.66	30.41	33.18
1 ⅝	16.37	17.86	19.35	20.84	23.80	26.80	29.77	32.75	35.78
1 ¾	17.54	19.14	20.73	21.33	25.50	28.71	31.90	35.09	38.28
2	18.71	20.41	22.12	23.82	27.20	30.60	34.03	37.43	40.80

TABLE 96. WEIGHT OF SQUARE STEEL.
Length, 1 Foot.

Side of Square	Weight	Side of Square	Weight	Side of Square	Weight	Side of Square	Weight
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.
¼	0.53	1 ⅛	1.61	1 ⅝	5.06	2 ¼	21.3
⅕	0.83	1 ⅜	1.76	1 ¾	5.32	2 ⅝	23.5
⅙	1.20	1 ⅝	1.91	1 ⅞	5.86	2 ¾	25.7
⅚	1.63	1 ⅞	2.08	1 ⅺ	6.43	2 ⅺ	28.1
1	2.13	1 ⅺ	2.25	1 ⅻ	7.03	3	30.6
1 ⅛	2.69	2	2.45	1 ⅻ	7.71	3 ¼	35.9
1 ¼	3.32	2 ¼	2.61	1 ⅻ	8.31	3 ½	41.7
1 ⅓	4.02	2 ½	2.81	1 ⅻ	8.99	3 ¾	47.8
1 ⅝	4.79	2 ⅝	2.99	1 ⅻ	9.80	4	54.4
1 ⅞	5.62	2 ¾	3.19	1 ⅻ	10.4	4 ¼	61.5
2	6.51	2 ⅺ	3.40	1 ⅻ	11.2	4 ½	68.9
2 ⅛	7.48	2 ⅻ	3.61	1 ⅻ	12.0	4 ¾	76.8
2 ¼	8.51	2 ⅻ	3.84	1 ⅻ	12.8	5	85.1
2 ⅓	9.60	2 ⅻ	4.11	2	13.6	5 ¼	93.8
2 ½	1.08	2 ⅻ	4.31	2 ¼	15.4	5 ½	102.9
2 ⅞	1.20	2 ⅻ	4.57	2 ½	17.2	5 ¾	112.4
3	1.33	2 ⅻ	4.80	2 ⅝	19.2	6	122.5
3 ⅛	1.47						

TABLE 97.—WEIGHT OF ROUND STEEL.
Length, 1 Foot

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Cwts.
$\frac{1}{8}$	.042	1	2.68	$2\frac{3}{8}$	15.1	8	15.27
$\frac{5}{16}$	.065	$1\frac{1}{16}$	2.84	$2\frac{7}{16}$	15.9	$8\frac{1}{2}$	17.25
$\frac{3}{8}$	.094	$1\frac{1}{8}$	3.02	$2\frac{1}{2}$	16.8	9	19.32
$\frac{7}{16}$	.128	$1\frac{3}{8}$	3.21	$2\frac{5}{8}$	18.4	$9\frac{1}{2}$	21.54
$\frac{1}{2}$	.167	$1\frac{1}{2}$	3.38	$2\frac{3}{4}$	20.2	10	23.87
$\frac{9}{16}$	.211	$1\frac{5}{8}$	3.57	$2\frac{7}{8}$	22.1	$10\frac{1}{2}$	26.31
$\frac{5}{8}$	.261	$1\frac{3}{4}$	3.77	3	24.1	11	28.87
$\frac{11}{16}$	.317	$1\frac{7}{8}$	3.98	$3\frac{1}{8}$	26.1	$11\frac{1}{2}$	31.52
$\frac{3}{4}$	.376	$1\frac{1}{2}$	4.17	$3\frac{1}{4}$	28.3	12	34.36
$\frac{13}{16}$	.441	$1\frac{5}{4}$	4.38	$3\frac{3}{8}$	30.4	$12\frac{1}{2}$	37.32
$\frac{7}{8}$	.511	$1\frac{9}{8}$	4.61	$3\frac{1}{2}$	32.8	13	40.32
$\frac{15}{16}$	.587	$1\frac{11}{8}$	4.80	$3\frac{5}{8}$	35.1	$13\frac{1}{2}$	43.49
1	.658	$1\frac{1}{2}$	5.05	$3\frac{7}{8}$	37.6	14	46.76
$1\frac{1}{16}$	.735	$1\frac{1}{4}$	5.10	$3\frac{7}{8}$	40.1	$14\frac{1}{2}$	50.17
$1\frac{1}{8}$	.815	$1\frac{3}{8}$	6.01	4	42.8	15	53.68
$1\frac{3}{8}$	.941	$1\frac{1}{2}$	6.52	$4\frac{1}{8}$	46.3	$15\frac{1}{2}$	57.33
$1\frac{1}{2}$	1.04	$1\frac{5}{8}$	7.05	$4\frac{1}{4}$	54.1	16	61.08
$1\frac{5}{8}$	1.15	$1\frac{3}{4}$	7.62	$4\frac{3}{8}$	60.3	$16\frac{1}{2}$	64.96
$1\frac{3}{4}$	1.29	$1\frac{7}{8}$	8.19	5	66.9	17	68.96
$1\frac{7}{8}$	1.30	$1\frac{9}{8}$	8.78	$5\frac{1}{4}$	73.7	$17\frac{1}{2}$	73.08
2	1.50	$1\frac{1}{2}$	9.39	$5\frac{1}{2}$	80.9	18	77.31
$2\frac{1}{16}$	1.63	$1\frac{1}{4}$	10.0	$5\frac{3}{8}$	88.4	19	81.64
$2\frac{1}{8}$	1.77	2	10.7	6	96.2	20	85.45
$2\frac{1}{4}$	1.90	$2\frac{1}{16}$	11.3	Inches. Cwts.		21	10.53
$2\frac{3}{8}$	2.04	$2\frac{1}{8}$	12.0			22	11.55
$2\frac{1}{2}$	2.20	$2\frac{3}{16}$	12.9			23	12.63
$2\frac{5}{8}$	2.35	$2\frac{1}{4}$	13.6			24	13.74
$2\frac{3}{4}$	2.51	$2\frac{5}{16}$	14.3	$7\frac{1}{2}$	134.2		

TABLE 98.—STEEL PLATES ORDINARY SIZES.

Thick- ness.	Maxi- mum Area	Maxi- mum Length	Maxi- mum Width	Thick- ness.	Maxi- mum Area	Maxi- mum Length	Maxi- mum Width
Inch.	Sq. Ft.	Feet.	Feet.	Inch.	Sq. Ft.	Feet.	Feet.
$\frac{1}{16}$	28	14	4	$\frac{7}{16}$	98	40	7
$\frac{3}{16}$	31	18	$4\frac{1}{2}$	$\frac{1}{2}$	105	40	$7\frac{1}{2}$
$\frac{1}{8}$	40	22	5	$\frac{5}{8}$	115	40	$8\frac{1}{2}$
$\frac{9}{16}$	50	25	$5\frac{1}{4}$	$\frac{3}{4}$	125	37	$8\frac{1}{4}$
$\frac{1}{2}$	65	30	$5\frac{1}{2}$	$\frac{7}{8}$	125	31	$8\frac{1}{8}$
$\frac{5}{8}$	72	33	6	1	125	31	$8\frac{1}{8}$
$\frac{3}{4}$	75	35	$6\frac{1}{4}$	$1\frac{1}{8}$	110	25	
$\frac{7}{8}$	85	38	$6\frac{1}{2}$	$1\frac{1}{4}$	110	25	

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

Thick- ness	Width.								
	5½	6	6½	7	8	9	10	11	12
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	4.68	5.10	5.53	5.95	6.83	7.66	8.51	9.36	10.21
$\frac{5}{16}$	5.84	6.38	6.91	7.44	8.50	9.57	10.63	11.70	12.76
$\frac{3}{8}$	7.02	7.66	8.29	8.93	10.20	11.48	12.76	14.04	15.31
$\frac{7}{16}$	8.19	8.93	9.68	10.42	11.90	13.39	14.89	16.37	17.86
$\frac{1}{2}$	9.36	10.21	11.06	11.91	13.60	15.31	17.01	18.71	20.42
$\frac{9}{16}$	10.53	11.48	12.44	13.40	15.30	17.23	19.14	21.05	22.97
$\frac{5}{8}$	11.70	12.76	13.82	14.89	17.00	19.14	21.27	23.39	25.52
$\frac{11}{16}$	12.87	14.04	15.20	16.37	18.70	21.05	23.39	25.73	28.07
$\frac{3}{4}$	14.04	15.31	16.59	17.86	20.40	22.97	25.52	28.07	30.62
$\frac{13}{16}$	15.21	16.59	17.97	19.35	22.10	24.88	27.65	30.41	33.18
$\frac{7}{8}$	16.37	17.86	19.35	20.84	23.80	26.80	29.77	32.75	35.73
$\frac{15}{16}$	17.54	19.14	20.73	21.33	25.50	28.71	31.90	35.09	38.28
1	18.71	20.41	22.12	23.82	27.20	30.60	34.03	37.43	40.80

TABLE 96. WEIGHT OF SQUARE STEEL.
Length, 1 Foot.

Side of Square.	Weight	Side of Square.	Weight	Side of Square.	Weight.	Side of Square.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.
$\frac{1}{8}$	0.53	$\frac{11}{16}$	1.61	$\frac{1}{32}$	5.06	$2\frac{1}{2}$	21.3
$\frac{5}{32}$	0.83	$\frac{3}{4}$	1.76	$\frac{1}{4}$	5.32	$2\frac{3}{4}$	23.5
$\frac{3}{16}$	1.20	$\frac{7}{8}$	1.91	$1\frac{1}{16}$	5.86	$2\frac{7}{8}$	25.7
$\frac{7}{32}$	1.63	$\frac{15}{16}$	2.08	$\frac{1}{8}$	6.48	$2\frac{15}{16}$	28.1
$\frac{1}{4}$	2.13	$\frac{1}{2}$	2.25	$\frac{1}{16}$	7.03	3	30.6
$\frac{9}{32}$	2.69	$\frac{27}{32}$	2.45	$\frac{1}{10}$	7.71	$3\frac{1}{4}$	35.9
$\frac{5}{16}$	3.32	$\frac{7}{8}$	2.61	$\frac{3}{32}$	8.31	$3\frac{1}{2}$	41.7
$\frac{11}{32}$	4.02	$\frac{15}{16}$	2.81	$\frac{1}{8}$	8.99	$3\frac{3}{4}$	47.8
$\frac{3}{8}$	4.79	$\frac{1}{2}$	2.99	$\frac{1}{16}$	9.80	4	54.4
$\frac{13}{32}$	5.62	$\frac{31}{32}$	3.19	$\frac{1}{10}$	10.4	4½	61.5
$\frac{7}{16}$	6.51	1	3.40	$\frac{1}{8}$	11.2	4¾	68.9
$\frac{15}{32}$	7.48	$1\frac{1}{32}$	3.61	$\frac{1}{4}$	12.0	5	76.8
$\frac{1}{2}$	8.51	$1\frac{1}{16}$	3.84	$\frac{1}{8}$	12.8	5½	85.1
$\frac{17}{32}$	9.60	$1\frac{1}{8}$	4.11	$\frac{3}{16}$	13.6	5¾	93.8
$\frac{9}{16}$	10.8	$1\frac{1}{4}$	4.31	$\frac{1}{4}$	15.1	$5\frac{1}{2}$	102.9
$\frac{19}{32}$	1.20	$1\frac{3}{8}$	4.57	$\frac{1}{2}$	17.2	$5\frac{3}{4}$	112.8
$\frac{5}{8}$	1.43	$1\frac{1}{2}$	4.80	$\frac{3}{8}$	19.2	6	122.5
$\frac{21}{32}$	1.47						

TABLE 97.—WEIGHT OF ROUND STEEL.
Length, 1 Foot.

Diam. Weight.		Diam. Weight.		Diam. Weight		Diam. Weight.	
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Cwts.
$\frac{1}{8}$	0.42	1	2.68	$2\frac{1}{8}$	15.1	8	1.327
$\frac{3}{16}$	0.65	$1\frac{1}{16}$	2.84	$2\frac{1}{16}$	15.9	$8\frac{1}{2}$	1.725
$\frac{1}{4}$	0.94	$1\frac{1}{8}$	3.02	$2\frac{1}{8}$	16.8	9	1.932
$\frac{5}{16}$	1.28	$1\frac{3}{16}$	3.21	$2\frac{3}{16}$	18.4	$9\frac{1}{2}$	2.154
$\frac{3}{8}$	1.67	$1\frac{1}{2}$	3.38	$2\frac{1}{2}$	20.2	10	2.387
$\frac{7}{16}$	2.11	$1\frac{5}{8}$	3.57	$2\frac{3}{8}$	22.1	$10\frac{1}{2}$	2.631
$\frac{1}{2}$	2.61	$1\frac{3}{4}$	3.77	3	24.1	11	2.887
$\frac{9}{16}$	3.17	$1\frac{7}{8}$	3.98	$3\frac{1}{8}$	26.1	$11\frac{1}{2}$	3.152
$\frac{5}{8}$	3.76	1 $\frac{1}{2}$	4.17	$3\frac{1}{4}$	28.3	12	3.436
$\frac{11}{16}$	4.41	$1\frac{5}{8}$	4.38	$3\frac{3}{8}$	30.4	$12\frac{1}{2}$	3.732
$\frac{3}{4}$	5.11	$1\frac{3}{4}$	4.61	$3\frac{1}{2}$	32.8	13	4.032
$\frac{13}{16}$	5.87	$1\frac{1}{2}$	4.80	$3\frac{5}{8}$	35.1	$13\frac{1}{2}$	4.349
$\frac{7}{8}$	6.68	$1\frac{1}{4}$	5.05	$3\frac{3}{4}$	37.6	14	4.676
$\frac{15}{16}$	7.55	$1\frac{1}{8}$	5.19	$3\frac{7}{8}$	40.1	$14\frac{1}{2}$	5.317
$\frac{17}{16}$	8.45	$1\frac{1}{4}$	6.01	4	42.8	15	5.668
$\frac{19}{16}$	9.41	$1\frac{3}{8}$	6.52	$4\frac{1}{4}$	46.3	$15\frac{1}{2}$	5.733
$\frac{21}{16}$	1.04	$1\frac{1}{2}$	7.05	$4\frac{1}{2}$	54.1	16	6.108
$\frac{23}{16}$	1.15	$1\frac{5}{8}$	7.62	$4\frac{3}{4}$	60.3	$16\frac{1}{2}$	6.496
$\frac{25}{16}$	1.29	$1\frac{3}{4}$	8.19	5	66.9	17	6.896
$\frac{27}{16}$	1.30	$1\frac{7}{8}$	8.78	$5\frac{1}{4}$	73.7	$17\frac{1}{2}$	7.308
$\frac{29}{16}$	1.50	1 $\frac{1}{2}$	9.39	$5\frac{1}{2}$	80.9	18	7.731
$\frac{31}{16}$	1.63	$1\frac{1}{4}$	10.0	$5\frac{3}{4}$	88.4	19	8.614
$\frac{33}{16}$	1.77	2	10.7	6	96.2	20	9.545
$\frac{35}{16}$	1.90	$2\frac{1}{16}$	11.3	Inches. Cwts.		21	10.53
$\frac{37}{16}$	2.04	$2\frac{1}{8}$	12.0			22	11.55
$\frac{39}{16}$	2.20	$2\frac{1}{4}$	12.9	$6\frac{1}{2}$	1.008	23	12.63
$\frac{41}{16}$	2.35	$2\frac{1}{2}$	13.6	7	1.169	24	13.74
$\frac{43}{16}$	2.51	$2\frac{3}{8}$	14.3	$7\frac{1}{2}$	1.342		

TABLE 98.—STEEL PLATES ORDINARY SIZES.

Thick- ness.	Maxi- mum Area.	Maxi- mum Length	Maxi- mum Width	Thick- ness.	Maxi- mum Area	Maxi- mum Length	Maxi- mum Width
In. h.	Sq. Ft.	Feet.	Feet.	Inch	Sq. Ft.	Feet.	Feet.
$\frac{3}{16}$	28	14	4	$\frac{7}{16}$	98	40	7
$\frac{1}{8}$	31	18	$4\frac{1}{2}$	$\frac{1}{2}$	105	40	$7\frac{1}{2}$
$\frac{5}{16}$	40	22	5	$\frac{9}{16}$	115	40	$8\frac{1}{2}$
$\frac{3}{8}$	50	25	$5\frac{1}{2}$	$\frac{1}{4}$	125	37	$8\frac{1}{4}$
$\frac{7}{16}$	65	30	7	$\frac{1}{2}$	125	34	$8\frac{1}{2}$
$\frac{1}{2}$	72	33	6	1	125	31	$8\frac{1}{4}$
$\frac{9}{16}$	75	35	$6\frac{1}{2}$	$1\frac{1}{8}$	110	28	$8\frac{1}{4}$
$\frac{5}{8}$	85	38	$6\frac{1}{2}$	$1\frac{1}{4}$	110	25	$8\frac{1}{4}$

TABLE 99.—WEIGHT PER SQUARE FOOT OF STEEL SHEET
AND PLATES.
(The Steel Pipe Company.)

Thickness.			Weight per Square Foot Pounds.	Thickness.			Weight per Square Foot Pounds.
Inch.	Inch.	Imperial Standard Gauge.		Inch.	Inch.	Imperial Standard Gauge.	
.0625	$\frac{1}{16}$	.	2.55	.2187	$\frac{1}{32}$	..	8.97
.064		16	2.61	.232	...	4	9.16
.072		15	2.94	.25	$\frac{1}{8}$	..	10.20
.080		14	3.26	.252	...	3	10.28
.092		13	3.75	.276	.	2	11.26
.09375	$\frac{3}{32}$	...	3.87	.300	.	1	12.24
.104		12	4.24	.3125	$\frac{5}{16}$	.	12.75
.116	...	11	4.73	.375	$\frac{3}{8}$	...	15.30
.125	$\frac{1}{8}$	.	5.10	.4375	$\frac{7}{16}$	.	17.85
.128		10	5.22	.500	$\frac{1}{2}$	.	20.40
.144		9	5.87	.5625	$\frac{9}{16}$	.	22.95
.15625	$\frac{5}{16}$	..	6.37	.625	$\frac{5}{8}$	...	25.50
.160	...	8	6.53	.6875	$\frac{11}{16}$	.	28.05
.176		7	7.18	.75	$\frac{3}{4}$	.	30.40
.1875	$\frac{3}{16}$	..	7.65	.875	$\frac{7}{8}$	..	35.70
.192		6	7.83	1.00	1	.	40.80
.212		5	8.65				

TABLE 100. CHISEL STEEL WEIGHT.
Length, 1 Foot.

Diameter across the Sides.	Weight.		Diameter across the Sides.	Weight.	
	Hexagonal Section.	Octagonal Section.		Hexagonal Section.	Octagonal Section.
Inches.	Pounds.	Pounds.	Inches.	Pounds.	Pounds.
$\frac{1}{8}$	414	437	1	2.91	2.82
$\frac{1}{4}$	736	704	1 $\frac{1}{4}$	3.73	3.56
$\frac{3}{8}$	1.15	1.10	1 $\frac{1}{2}$	4.60	4.40
$\frac{1}{2}$	1.63	1.58	1 $\frac{3}{4}$	5.57	5.32
$\frac{5}{8}$	2.25	2.16	1 $\frac{7}{8}$	6.63	6.34

OVAL PLATE SECTION

Width x Thickness.

Inches
 $\frac{1}{4}$ x $\frac{1}{8}$
1 x $\frac{1}{2}$
1 $\frac{1}{4}$ x $\frac{3}{8}$

Weight

Pounds.
2.53
1.72
2.37

TABLE 101.—SIZES, WEIGHTS, LENGTHS, AND BREAKING STRESS OF IRON WIRE.

Issued by the Iron and Steel Wire Manufacturers' Association,
January 15, 1884.

(Imperial Standard Wire-Gauge.)

Size on Wire Gauge	Diameter		Sectional Area.	Weight of		Length of Cwl.	Breaking Stress.	
	Inch.	Millimetres.		100 Yards.	Mile.		Annealed.	Bright.
			Sq. Ins.	Lbs.	Lbs.	Yards.	Lbs.	Lbs.
7/0	·500	12·7	·1963	198·4	3404	58	10470	15700
6/0	·464	11·8	·1691	166·5	2930	67	9017	13525
5/0	·432	11	·1466	144·4	2541	78	7814	11725
4/0	·400	10·2	·1257	123·8	2179	91	6702	10052
3/0	·372	9·4	·1087	107·1	1885	105	5796	8694
2/0	·348	8·8	·0951	93·7	1649	120	5072	7608
1/0	·324	8·2	·0824	81·2	1420	138	4397	6595
1	·300	7·6	·0707	69·6	1225	161	3770	5655
2	·276	7	·0598	58·9	1037	190	3190	4783
3	·252	6·4	·0499	49·1	864	228	2660	3990
4	·232	5·9	·0428	41·6	732	269	2254	3381
5	·212	5·4	·0353	34·8	612	322	1883	2824
6	·192	4·9	·0290	28·5	502	393	1544	2316
7	·176	4·5	·0243	24	422	467	1298	1946
8	·160	4·1	·0201	19·8	348	566	1072	1608
9	·144	3·7	·0163	16	282	700	869	1303
10	·128	3·3	·0129	12·7	223	882	687	1030
11	·116	3	·0106	10·4	183	1077	564	845
12	·104	2·6	·0085	8·4	148	1333	454	680
13	·092	2·3	·0066	6·5	114	1723	355	532
14	·080	2	·0050	5	88	2240	268	402
15	·072	1·8	·0041	4	70	2800	218	326
16	·064	1·6	·0032	3·2	56	3500	172	257
17	·056	1·4	·0025	2·4	42	4667	131	197
18	·048	1·2	·0018	1·8	32	6222	97	145
19	·040	1	·0013	1·2	21	9333	67	100
20	·036	0·9	·0010	1	18	11200	55	82

Indian Government Telegraphs.

TELEGRAPH WIRES FOR LINES AND CABLES.

The data for inspection as to size, weight, tensile strength and ductility for all sizes of telegraph wires in use by the Indian Government, are given in the Tables 102 and 103, for line wire and cable wire. The wires are of iron, galvanised. In testing the wire for tensile strength, it is loaded by direct weight vertically and is required at first to lift a weight equal to $\frac{1}{15}$ ths of the maximum proof load. If the wire supports the load without failure, the load is gradually augmented by four successive advances, until the wire fails or the maximum load is reached. Testing for ductility, the piece of wire, after failure by load, or after supporting the maximum load, is gripped by two vices and twisted. The vices are 6 inches apart for sizes above 150 pounds per mile; and 3 inches apart for sizes of 150 pounds or less. The number of twists applied is reduced as the proportional resistance to load is greater, according to the scale of loads and relative twists given in the Tables.

A margin of $\frac{1}{2}$ per cent. deviation either way from the required weight of wire weighing 600 pounds per mile and upwards is allowed, and for wires of less weight, 2 per cent. is allowed.

Weld joints are not allowed in cable-wire, except in the case of cable wire weighing 900 pounds per mile, sent to Calcutta, in which, if in coils of from 400 to 500 pounds weight, one weld may be introduced.

The maximum resistances per inch of wires, at 60° F. not to be exceeded, are as follows:

No.	Units	N.	Units
1	4.5	9 $\frac{1}{2}$	18
2	6.5	12 $\frac{1}{2}$	34
3	7.25	15 $\frac{1}{2}$	72
4	8	16	90
5	9	16	108
6	12		

The wires are to bear winding round bars of different diameters, without cracking, as follows:—

Nos.	Bars.
3, and 4	4 inches in diameter.
5 " 5 $\frac{1}{2}$	2 $\frac{1}{2}$ " "
7 " 9 $\frac{1}{2}$	2 " "
12 " 15 $\frac{1}{2}$	1 " "
16 " 17	$\frac{1}{2}$ " "

TABLE 102—GALVANISED IRON TELEGRAPH WIRE—STANDARD SIZES, WEIGHTS AND TESTS.
(India Stores Department.)

LINE WIRE.

Nominal Size	Diameter	Weight per Mile	Weight of Ten feet	Tests for Strength and Ductility.						Weight of each coil.	
				Load.	Twists.	Load.	Twists.	Load.	Twists.	Min. lbs.	Maxi- mum lbs.
1	2.164	1206	2.272	3700	11	3800	10	4100	7	40	120
2	2.241	906	1.704	2775	14	2850	13	3076	10	45	105
3	2.325	770	1.420	2312	15	2375	13	2582	11	45	105
4	2.405	675	1.278	2081	16	2137	14	2437	12	45	105
5	2.479	600	1.136	1850	17	1900	15	2250	13	45	105
6	2.551	540	1.032	1688	19	1725	17	2050	15	80	105
7	2.620	490	.948	1525	22	1650	21	1880	18	70	80
8	2.688	450	.884	1400	24	1550	23	1780	20	70	80
9	2.754	420	.828	1300	27	1450	26	1680	23	70	80
10	2.819	390	.780	1225	30	1375	29	1600	26	70	80
11	2.883	360	.732	1150	33	1300	32	1525	29	70	80
12	2.946	330	.684	1075	36	1225	35	1450	32	70	80
13	3.008	300	.636	1000	39	1150	38	1375	35	70	80
14	3.069	270	.588	925	42	1075	41	1300	38	70	80
15	3.129	240	.540	850	45	1000	44	1225	41	70	80
16	3.188	210	.492	775	48	925	47	1150	44	70	80
17	3.246	180	.444	700	51	850	50	1075	47	70	80
18	3.303	150	.396	625	54	775	53	1000	50	70	80
19	3.359	120	.348	550	57	700	56	925	53	70	80
20	3.414	90	.300	475	60	625	59	850	56	70	80
21	3.468	60	.252	400	63	550	62	775	59	70	80
22	3.521	30	.204	325	66	475	65	700	62	70	80

TABLE 103—GALVANISED TELEGRAPH WIRE—STANDARD SIZES, WEIGHTS AND TESTS.
(India Stores Department)

TABLE WIRE.

Nominal Size	Weight per Mile	Tests for Strength and Ductility						Weight of each cable	
		Load	Twists	Load	Twists	Load	Twists	Min- imum	Maxi- mum
No 8	Lbs 925	Lbs 3165	10	Lbs 3165	9	Lbs 3240	8	Lbs. 210	Lbs. 280
3	900	3075	10	3150	9	3225	8	210	280
4	750	2562	11	2625	10	2687	9	350	160
5	600	2050	12	2100	10	2150	9	350	160
6	450	1540	14	1580	12	1625	11	320	130
7	300	1025	17	1050	15	1075	14	220	130

TABLE 104.—SHEET AND HOOP-IRON GAUGE.
 Issued by the South Staffordshire Iron Masters' Association,
 March 1, 1884.

Parts of Inch.	No. on Gauge.	Thick- ness.	Weight of One Square Foot.		Parts of Inch.	No. on Gauge.	Thick- ness.	Weight of One Square Foot.	
			Iron.	Steel.				Iron.	Steel.
Inch.		Inch.	Lbs.		Inch.		Inch.	Lbs.	
1	13°	1.0000	40	40.83	1	20	.0392	1.57	1.60
	14°	.9583	38.33	39.13		21	.0349	1.40	1.43
	13°	.9167	36.67	37.44	1/32	22	.0312	1.25	1.28
7/16	12°	.8750	35.00	35.73		23	.0278	1.11	1.13
	11°	.8333	33.33	34.03		24	.0247	.992	1.01
	10°	.7917	31.67	32.33	1/16	25	.0220	.883	.901
3/8	9°	.7500	30.00	30.63		26	.0196	.784	.800
	8°	.7083	28.33	28.92		27	.0174	.696	.710
	7°	.6666	26.67	27.23	1/8	28	.015625	.625	.638
1/2	6°	.6250	25.00	25.42		29	.0139	.556	.568
	5°	.5833	23.33	23.82		30	.0123	.492	.502
	4°	.5416	21.67	22.12	3/16	31	.0110	.440	.449
5/8	3°	.5000	20.00	20.42		32	.0098	.392	.400
	2°	.4452	18.33	18.69		33	.0087	.349	.356
	1°	.3964	16.67	17.02	1/4	34	.0077	.308	.314
3/4	1	.3532	15.00	15.31		35	.0069	.276	.282
	2	.3147	13.33	13.61		36	.0061	.244	.249
	3	.2804	11.67	12.01	1/2	37	.0054	.216	.221
7/8	4	.2500	10.00	10.21		38	.0048	.192	.196
	5	.2225	8.90	9.08		39	.0043	.172	.176
	6	.1981	7.92	8.09	1	40	.00386	.154	.157
1	7	.1764	7.06	7.20		41	.00343	.138	.140
	8	.1570	6.38	6.52		42	.00306	.123	.126
1 1/8	9	.1398	6.51	6.65	1 1/4	43	.00272	.109	.111
	10	.1250	5.00	5.10		44	.00242	.097	.099
	11	.1113	4.45	4.54		45	.00215	.086	.088
1 1/4	12	.0991	3.97	4.05	1 1/2	46	.00192	.077	.079
	13	.0882	3.53	3.55		47	.00170	.068	.069
	14	.0785	3.14	3.21		48	.00152	.061	.062
1 1/2	15	.0699	2.80	2.86	1 3/4	49	.00135	.054	.055
	16	.0625	2.50	2.55		50	.00120	.048	.049
	17	.0556	2.23	2.27		51	.00107	.043	.044
1 3/4	18	.0495	1.98	2.02	2	52	.00095	.038	.039
	19	.0440	1.76	1.80					

TABLE III.—LAP-WELDED
(Andrew and
WEIGHT OF ONE

Thickness by Imperial Wire Gauge.			External			
Wire Gauge.	Inches.	Millimetres.	I	1½	1¾	1⅞
			Lbs.	Lbs.	Lbs.	Lbs.
16	·064	1·626	0·627	0·711	...	...
15	·072	1·829	0·700	0·794	0·888	0·982
14	·080	2·032	0·771	0·875	0·980	1·085
13	·092	2·337	0·875	0·995	1·116	1·236
12	·104	2·642	0·976	1·112	1·248	1·384
11	·116	2·946	1·074	1·226	1·377	1·529
10	·128	3·251	1·169	1·336	1·504	1·671
9	·144	3·658	1·291	1·472	1·668	1·846
8	·164	4·064	1·407	1·617	1·826	2·036
7	·176	4·470	1·519	1·744	1·979	2·210
6	·192	4·877	1·624	1·876	2·127	2·378
5	·212	5·385	1·749	2·027	2·304	2·582
4	·232	5·893	1·866	2·169	2·473	2·777
3	·252	6·401	1·974	2·304	2·634	2·963
2	·276	7·010	2·092	2·454	2·815	3·176
1	·300	7·620	2·199	2·592	2·984	3·377
¼ in.	·125	3·175	1·145	1·309	1·473	1·636
⅜ "	·187	4·762	1·595	1·841	2·086	2·332
½ "	·250	6·350	1·963	2·291	2·618	2·945
⅝ "	·313	7·937	2·250	2·659	3·068	3·477
¾ "	·375	9·525	2·454	2·945	3·436	3·927
⅞ "	·437	11·112	2·577	3·150	3·723	4·295
1 "	·500	12·700	2·618	3·272	3·927	4·581

Note.—The most common thick-
* The weight per lineal foot of a steel tube is given by multiply-

IRON BOILER TUBES.*

James Stewart.)

FOOT IN LENGTH

Diameter in inches.							
1½	1¾	1½	1¾	2	2¼	2½	2¾
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1-077	1-171	1-265	1-359				
1-190	1-294	1-399	1-504	1-608	1-713	1-818	1-922
1-356	1-477	1-597	1-718	1-838	1-959	2-079	2-199
1-520	1-636	1-793	1-929	2-065	2-201	2-337	2-473
1-681	1-833	1-985	2-137	2-288	2-440	2-592	2-744
1-839	2-007	2-174	2-342	2-509	2-677	2-844	3-012
2-045	2-233	2-422	2-610	2-799	2-987	3-176	3-364
2-245	2-456	2-664	2-873	3-083	3-292	3-502	3-711
2-440	2-671	2-901	3-131	3-362	3-592	3-822	4-053
2-630	2-881	3-132	3-384	3-635	3-886	4-138	4-389
2-859	3-137	3-414	3-692	3-969	4-247	4-524	4-802
3-081	3-384	3-688	3-992	4-295	4-599	4-903	5-206
3-293	3-623	3-953	4-283	4-613	4-943	5-273	5-602
3-538	3-899	4-260	4-621	4-983	5-344	5-705	6-067
3-770	4-163	4-555	4-948	5-341	5-733	6-126	6-519
1-800	1-963	2-127	2-291	2-454	2-618	2-782	2-945
2-577	2-822	3-068	3-313	3-559	3-804	4-050	4-295
3-272	3-600	3-927	4-254	4-581	4-908	5-236	5-563
3-886	4-295	4-704	5-113	5-522	5-931	6-340	6-749
4-418	4-909	5-400	5-890	6-381	6-872	7-363	7-854
58	5-440	6-013	6-586	7-159	7-731	8-304	8-877
	5-890	6-545	7-199	7-854	8-508	9-163	9-817

iron tube by 1-02

TABLE 105. - LAP-WELDED IRON
(Andrew and
WEIGHT OF ONE

Thickness by Imperial Wire Gauge	External Diameter						
	2½	2¾	2½	2¾	3	3½	3¾
Wire Gauge	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
16							...
15							...
14	...	...	...	...	...	...	...
13	2 320	2 410	2 511	2 681	2 802	3 018	3 290
12	2 609	2 745	2 882	3 018	3 154	3 290	3 426
11	2 896	3 048	3 200	3 351	3 503	3 655	3 806
10	3 179	3 347	3 514	3 682	3 850	4 017	4 184
9	3 553	3 741	3 930	4 118	4 307	4 495	4 683
8	3 921	4 130	4 339	4 549	4 758	4 968	5 177
7	4 283	4 514	4 744	4 974	5 205	5 435	5 665
6	4 640	4 892	5 143	5 394	5 646	5 897	6 148
5	5 079	5 357	5 634	5 912	6 189	6 467	6 744
4	5 510	5 814	6 117	6 421	6 725	7 028	7 332
3	5 932	6 262	6 592	6 922	7 252	7 582	7 911
2	6 428	6 789	7 150	7 512	7 873	8 234	8 595
1	6 911	7 304	7 697	8 090	8 482	8 875	9 267
¾	3 101	3 272	3 436	3 600	3 763	3 927	4 090
⅝	4 541	4 786	5 031	5 277	5 522	5 768	6 013
½	5 890	6 218	6 545	6 872	7 200	7 527	7 854
⅓	7 159	7 568	7 977	8 386	8 795	9 204	9 613
¼	8 345	8 836	9 327	9 818	10 308	10 799	11 289
⅛	9 449	10 022	10 595	11 167	11 740	12 313	12 885
1/16	10 472	11 135	11 781	12 435	13 090	13 744	14 398

Note. The most common thickness of a steel tube is given by inch.

BOILER TUBES*—*continued.*

James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.								
3 $\frac{3}{8}$	3 $\frac{1}{2}$	3 $\frac{5}{8}$	3 $\frac{7}{8}$	3 $\frac{7}{8}$	4	4 $\frac{1}{4}$	4 $\frac{1}{2}$	4 $\frac{3}{4}$
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...
...
...
...
3.562	3.698	3.835	3.971	4.107	...	...	...	...
3.959	4.111	4.262	4.414	4.566	4.718	5.022	5.325	...
4.352	4.520	4.687	4.855	5.022	5.190	5.525	5.860	6.195
4.872	5.061	5.249	5.438	5.626	5.815	6.192	6.569	6.946
5.387	5.596	5.806	6.015	6.224	6.434	6.853	7.272	7.690
5.896	6.126	6.357	6.587	6.817	7.048	7.509	7.969	8.430
6.400	6.651	6.902	7.154	7.405	7.656	8.159	8.662	9.164
7.022	7.299	7.577	7.854	8.132	8.410	8.965	9.520	10.075
7.636	7.940	8.243	8.547	8.851	9.154	9.762	10.369	10.976
8.241	8.571	8.901	9.231	9.561	9.891	10.550	11.210	11.870
8.957	9.318	9.679	10.041	10.402	10.763	11.486	12.208	12.931
9.660	10.053	10.446	10.838	11.231	11.624	12.409	13.195	13.980
4.254	4.418	4.581	4.745	4.908	5.072	5.400	5.727	6.054
6.259	6.504	6.750	6.995	7.240	7.486	7.977	8.468	8.959
8.181	8.508	8.836	9.163	9.490	9.817	10.472	11.126	11.781
10.022	10.431	10.840	11.249	11.658	12.067	12.885	13.704	14.522
11.781	12.272	12.763	13.254	13.745	14.235	15.217	16.199	17.181
13.458	14.031	14.604	15.176	15.749	16.322	17.467	18.612	19.758
15.053	15.708	16.362	17.017	17.671	18.326	19.635	20.944	22.253

nesses are printed in dark figures.

plying the tabular weight of a like wrought-iron tube by 1.021

TABLE 105 LAP WELDED IRON
(Andrew and
WEIGHT OF ONE

Thickness by Internal Wire Gauge	External					
	5	5½	5¾	5⅞	6	6½
Wire Gauge.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
16			.	.	.	...
15	.	.	.	..	..	..
14	...	...	.	.	...	...
13	...	..	.	...	..	...
12	..	.	.	.	.	...
11	.	.	.	..	..	..
10	6.540	6.806				
9	7.323	7.700	8.077	8.454	8.831	9.208
8	8.109	8.528	8.947	9.366	9.785	10.204
7	8.891	9.352	9.812	10.273	10.734	11.195
6	9.667	10.170	10.672	11.175	11.678	12.180
5	10.630	11.185	11.740	12.295	12.850	13.405
4	11.584	12.191	12.798	13.406	14.013	14.621
3	12.530	13.189	13.849	14.509	15.169	15.828
2	13.654	14.376	15.099	15.821	16.544	17.266
1	14.765	15.551	16.336	17.122	17.907	18.692
$\frac{1}{8}$ " 10	6.381	6.709	7.036	7.363	7.690	8.017
$\frac{3}{16}$ "	9.450	9.940	10.431	10.922	11.413	11.904
$\frac{1}{4}$ "	12.435	13.090	13.744	14.399	15.053	15.708
$\frac{5}{16}$ "	15.340	16.158	16.976	17.794	18.612	19.430
$\frac{3}{8}$ "	18.162	19.144	20.126	21.108	22.090	23.071
$\frac{7}{16}$ "	20.903	22.048	23.194	24.339	25.485	26.630
$\frac{1}{2}$ "	23.562	24.871	26.180	27.489	28.798	30.107

Note. The most common thickness.
* The weight per lineal foot of a steel tube is given by multiplying

BOILER TUBE

James Stewart:

FOOT IN LENGTH.

Diameter in Inches.								
6½	7	7½	7¾	8	8½	9	9½	10
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...
...
...
...
...
...
...
9-962	10-339	...	...	...	...	...	...	...
11-042	11-460	...	...	...	...	...	...	...
12-116	12-577	13-038	13-499	13-959	14-420	14-880	15-341	15-815
13-186	13-688	14-191	14-694	15-196	15-699	16-204	16-710	17-216
14-515	15-070	15-625	16-180	16-735	17-290	17-845	18-400	18-955
15-835	16-443	17-050	17-658	18-265	18-872	19-480	20-087	20-694
17-148	17-807	18-467	19-127	19-787	20-446	21-106	21-766	22-426
18-712	19-434	20-157	20-879	21-602	22-324	23-047	23-769	24-492
20-263	21-048	21-834	22-619	23-405	24-190	24-976	25-761	26-546
8-672	8-989	9-327	9-654	9-981	10-308	10-636	10-963	11-290
12-886	13-376	13-867	14-358	14-849	15-340	15-831	16-322	16-813
17-017	17-671	18-326	18-980	19-635	20-289	20-944	21-598	22-253
21-067	21-885	22-703	23-521	24-339	25-157	25-975	26-791	27-612
25-035	26-017	26-998	27-980	28-962	29-944	30-925	31-907	32-889
28-921	30-066	31-212	32-357	33-502	34-648	35-793	36-938	38-084
32-725	34-034	35-343	36-652	37-961	39-270	40-579	41-888	43-197

nesses are printed in dark figure.

plying the tabular weight of a like wrought iron tube by 1.058

TABLE 105.—LAP-WELDED IRON
(Andrew and
WEIGHT OF ONE

Thickness by Imperial Wire Gauge.			External		
Wire Gauge	Inches.	Millimeters	Ø	Ø½	Ø¾
			1 in.	1 in.	1 in.
16	.064	1.626	...	...	...
15	.072	1.829	...	...	...
14	.080	2.032	...	...	...
13	.092	2.337	...	...	...
12	.104	2.642	...	...	...
11	.116	2.946	...	...	...
10	.128	3.251	...	...	...
9	.144	3.658	...	...	...
8	.160	4.064	...	...	...
7	.176	4.470	16.290	16.770	17.255
6	.192	4.877	17.722	18.230	18.738
5	.212	5.385	19.510	20.065	20.620
4	.232	5.893	21.302	21.909	22.517
3	.252	6.401	23.085	23.745	24.405
2	.276	7.016	25.215	25.937	26.660
1	.300	7.620	27.332	28.117	28.903
¾ in.	.375	9.525	33.871	34.852	35.834
½ in.	.500	12.700	44.506	45.815	47.124

Note.—The most common thickness of a steel tube is given by round.

TABLE 109.—J.A.P.-WELDED WROUGHT-IRON TUBES FOR ARTESIAN WELLS: WEIGHT PER LINEAL FOOT.
(Lloyd and Lloyd.)

SWELLED JOINTS. Screwed together, External and Internal Screws.										
External Diameter, inches	2	2½	2½	2½	3	3½	3½	3½	4	Inches, Thickness, Weight.
Thickness, I. W. G. No.	11	11	11	11	11	10	10	10	9	
Weight per lineal foot, lbs.	2-347	2-659	2-971	3-283	3-591	4-344	4-693	5-041	5-982	6-316
External Diameter, inches	4½	4½	5	5	5½	5½	7	7	7	Inches, Thickness, Weight.
Thickness, I. W. G. No.	9	8	8	8	8	7	7	7	7	
Weight per lineal foot, lbs.	6-701	7-871	8-300	8-729	9-963	10-480	10-900	11-836	12-773	
FLUSH JOINTS. Screwed together, External and Internal Screws.										
External Diameter, inches	2	2½	2½	2½	3	3½	3½	3½	4	Inches
Weight in 1 inch thick	4-552	5-202	5-852	6-503	7-153	7-803	8-453	9-104	9-754	10-404
Weight in 1 inch thick	5-480	6-291	7-103	7-914	8-726	9-537	10-349	11-160	11-972	12-784
Weight in 1 inch thick	6-340	7-315	8-291	9-266	10-242	11-217	12-193	13-168	14-144	15-119
External Diameter, inches	4½	4½	5	5	5½	5½	7	7	7	Inches
Weight in 1 inch thick	11-054	11-705	12-355	13-006	13-656	14-306	14-957	15-607	16-258	16-908
Weight in 1 inch thick	13-598	14-407	15-219	16-030	16-843	17-653	18-463	19-273	20-083	20-893
Weight in 1 inch thick	16-096	17-070	18-046	19-021	19-997	20-972	21-948	22-923	23-898	24-873

TABLE 108.—LAP-WELDED CHARCOAL IRON BOILER TUBES
(NATIONAL TUBE WORKS COMPANY, U.S.A.).

(Haswell)

External Dia- meter	Thickness.		Weight per Lineal Foot	External Dia- meter	Thickness.		Weight per Lineal Foot.
Inches.	Wire Gauge.	Inch.	Pounds.	Inches.	Wire Gauge.	Inch.	Pounds.
1	10	.072	.71	4	10	.134	5.47
1 $\frac{1}{8}$	15	.072	.80	4 $\frac{1}{2}$	10	.134	5.82
1 $\frac{1}{4}$	15	.072	.89	4 $\frac{1}{2}$	10	.134	6.17
1 $\frac{3}{16}$	14	.083	1.08	4 $\frac{3}{4}$	10	.134	6.53
1 $\frac{1}{2}$	14	.083	1.13	5	9	.148	7.78
1 $\frac{3}{4}$	14	.083	1.24	5 $\frac{1}{4}$	9	.148	7.97
1 $\frac{7}{8}$	13	.095	1.53	5 $\frac{1}{2}$	9	.148	8.36
1 $\frac{1}{2}$	13	.095	1.66	6	8	.165	10.16
1 $\frac{1}{2}$	13	.095	1.78	7	8	.165	11.90
2	13	.095	1.91	8	8	.165	13.65
2 $\frac{1}{8}$	13	.095	2.04	9	7	.18	16.76
2 $\frac{1}{4}$	13 $\frac{1}{2}$	.095	2.16	10	6	.203	20.99
2 $\frac{3}{8}$	12	.109	2.61	11	5	.22	25.63
2 $\frac{1}{2}$	12	.109	2.75	12	4 $\frac{1}{2}$	.229	28.46
2 $\frac{3}{4}$	12	.109	3.14	13	4	.238	32.06
2 $\frac{7}{8}$	12	.109	3.18	14	3 $\frac{1}{2}$	.248	36.03
3	12 $\frac{1}{2}$	.109	3.33	15	3	.259	40.30
3 $\frac{1}{8}$	11	.12	3.96	16	2	.284	47.11
3 $\frac{1}{2}$	11	.12	4.28	17	1	.306	52.89
3 $\frac{3}{4}$	11	.12	4.60	18	0	.330	63.32

TABLE 109.—LAP-WELDED WROUGHT-IRON TUBES FOR ARTESIAN WELLS: WEIGHT PER LINEAL FOOT.
(Lloyd and Lloyd.)

SWELLED JOINTS: Screwed together, External and Internal Screws.												
External Diameter, inches	2	2½	2¾	2½	2¾	3	3½	3¾	3½	3¾	4	Inches.— Thickness.
Thickness, I. W. G., No.	11	11	11	11	11	11	10	10	10	10	9	Weight.
Weight per lineal foot, lbs.	2-347	2-659	2-971	3-283	3-596	4-344	4-693	5-041	5-392	5-932	6-316	
External Diameter, inches	4½	4¾	5	5½	5¾	5½	5¾	6	6½	7	7	Inches.— Thickness.
Thickness, I. W. G., No.	9	8	8	8	8	7	7	7	7	7	7	Weight.
Weight per lineal foot, lbs.	6-701	7-871	8-300	8-729	9-963	10-480	10-900	11-836	12-773			
FLUSH JOINTS: Screwed together, External and Internal Screws.												
External Diameter, inches	2	2½	2¾	3	3½	3¾	4	4½	4¾	5	5½	Inches.— Weight.
Weight in { pounds per { lineal foot {	4-552 5-480 6-340	5-202 6-291 7-315	5-852 7-103 8-291	6-503 7-914 9-266	7-153 8-726 10-242	7-808 9-537 11-217	8-458 10-349 12-193	9-104 11-160 13-168	9-754 11-972 14-444	10-404 12-784 15-119		
External Diameter, inches	4½	4¾	5	5½	5¾	6	6½	7	7	7	7	Inches.— Weight.
Weight in { pounds per { lineal foot {	11-054 13-398 16-086	11-705 14-407 17-070	12-355 15-219 18-046	13-006 16-080 19-021	13-656 16-843 19-997	14-306 17-653 20-972	14-957 18-465 21-948	16-533 20-088 23-898	17-558 21-711 25-850			

Internal Diameter, inches		8	9	10	11	12	13	14	15	16	17	18
Weight in pounds per lineal foot	$\frac{1}{4}$ inch thick	22	25	28	30	33	35	38	41	43	46	48
	$\frac{1}{2}$ " "	35	38	42	46	50	54	58	62	66	70	74
		47	52	58	63	68	73	78	84	89	94	100
Internal Diameter, inches		19	20	21	22	23	24	25	26	27	28	29
Weight in pounds per lineal foot	$\frac{1}{4}$ inch thick	51	54	56	59	62	64	67	69	72	75	78
	$\frac{1}{2}$ " "	78	82	86	90	95	97	101	105	109	113	118
		105	110	115	120	126	131	136	141	147	152	158
Internal Diameter, inches		29	30	31	32	33	34	35	36	37	38	39
Weight in pounds per lineal foot	$\frac{1}{4}$ inch thick	77	80	83	85	88	90	93	96	98	101	104
	$\frac{1}{2}$ " "	117	121	125	129	133	137	140	144	148	152	157
		157	162	168	173	178	183	188	194	199	204	209
Internal Diameter, inches		39	40	41	42	43	44	45	46	47	48	49
Weight in pounds per lineal foot	$\frac{1}{4}$ inch thick	104	106	109	111	114	117	119	122	124	127	130
	$\frac{1}{2}$ " "	155	160	164	168	172	176	180	184	188	192	197
		210	215	220	225	230	236	241	246	251	257	262

Steam-tubes, gas-tubes, and water-tubes, are made to weight, according to the "size" or bore; butt-welded. The weight of tubes of any given size varies very much with different manufacturers. Table III gives the average weights of gas-tubes, as made by several leading manufacturers. "Steam-tubes" and "water-tubes" are made to the same sizes as the gas-tubes, but of different weights. The tubes are proved by hydrostatic pressure, usually according to the following scale:—

Gas-tubes	50 lbs. per square inch.
Water-tubes	300 lbs. " "
Steam-tubes	500 lbs. " "

To find the thickness of a pipe, when the inside or the outside diameter, and the weight per lineal foot, are given.

Let d be the internal diameter, inches; D the external diameter, " the weight of pipe in pounds per lineal foot. Let, also, c be a constant of weight for the same material, say the weight of a straight bar 1 inch square, 1 foot long, in pounds. Then,

1st. When the internal diameter is given,

$$\text{The external diameter, } D = \sqrt{\frac{w}{.7854c} + d^2} \quad (1)$$

2nd. When the external diameter is given,

$$\text{The internal diameter, } d = \sqrt{D^2 - \frac{w}{.7854c}} \quad (2)$$

The other diameter having been ascertained by one or other of these formulas, half the difference of the external and internal diameters is the thickness of the pipe.

For example, a lead pipe of 1 inch bore, weighs 70 pounds for a 15-feet length. What is the thickness. The weight per lineal foot is $\left(\frac{70}{15}\right) = 4.666$ pounds, the weight c of 1-inch square bar, 1 foot long, is 4944 pounds; and by formula (1) the external diameter D is equal

$$\sqrt{\frac{4.666}{.7854 \times 4944} + 1^2} = \sqrt{1.202 + 1} = \sqrt{2.202} = 1.484$$

inches. Then $1.484 - 1 = .484$ inch, one half of which is .242 inch, nearly $\frac{1}{4}$ inch, the thickness of the lead pipe.

Conversely, taking the same pipe for example, let the external diameter, 1.484, be given, to find the internal diameter. By formula (2), the internal diameter, d , is equal to

$$\sqrt{1.484^2 - \frac{4.666}{.7854 \times 4.944}} = \sqrt{2.202 - 1.202} = \sqrt{1} = 1 \text{ inch bore.}$$

The constants for other metals are given in Table 89, page 221.

TABLE 111.—BUTT-WELDED GAS TUBES AND FITTINGS:
AVERAGE WEIGHT.

Tubes.			Fittings.		
Bore.	Weight per 100 Feet.	Length to weigh One Ton.	Weight of Ten Elbows.	Weight of Ten Tees.	Weight of Ten Crosses.
Inches.	Pounds.	Feet.	Lb. Oz.	Lb. Oz.	Lb. Oz.
$\frac{1}{8}$	26.3	8502	1 1	1 0	1 8
$\frac{1}{4}$	40.5	5532	1 7	1 8	1 14
$\frac{3}{8}$	57.5	3892	1 13	2 4	2 3
$\frac{1}{2}$	82.9	2700	2 15	3 0	3 4
$\frac{3}{4}$	122.0	1836	4 6	5 4	5 11
1	174.9	1281	6 4	7 10	9 2
$1\frac{1}{4}$	244.3	917	10 10	12 15	14 11
$1\frac{1}{2}$	310.2	722	15 8	16 7	18 10
$1\frac{3}{4}$	359.5	623	15 12	20 0	21 4
2	421.0	532	22 6	27 0	31 4
$2\frac{1}{4}$	515.0	435	30 2	32 8	41 4
$2\frac{1}{2}$	610.4	367	46 2	50 15	51 4
$2\frac{3}{4}$	658.8	340	55 10	68 8	80 10
3	759.3	295	73 8	85 5	88 12
$3\frac{1}{2}$	878.4	255	101 0	121 0	129 0
4	1032.3	217	126 0	144 0	158 0

Note 1.—Normal length, 14 feet.

Note 2.—Steam tubes and water tubes also are manufactured of the same bores.

TABLE 109.—LAP-WELDED WROUGHT IRON TUBES FOR ARTESIAN WELLS.—WEIGHT PER LINEAL FOOT.
(Lloyd and Lloyd.)

SWELLED JOINTS.—Screwed together, External and Internal Screws									
External Diameter, inches	2	2½	3	3½	4	4½	5	5½	6
Thickness, I. W. G. No.	11	11	11	10	9	9	8	8	7
Weight per lineal foot, lbs.	234	265	297	328	359	391	422	453	484
External Diameter, inches	4½	5	5½	6	6½	7	7	7	7
Thickness, I. W. G. No.	9	8	8	7	7	7	7	7	7
Weight per lineal foot, lbs.	570	787	830	872	914	956	1048	1090	1132
FLAT JOINTS.—Screwed together, External and Internal Screws									
External Diameter, inches	2	2½	3	3½	4	4½	5	5½	6
Weight in pounds per lineal foot	1 inch thick	1 inch thick	1 inch thick	1 inch thick	1 inch thick	1 inch thick	1 inch thick	1 inch thick	1 inch thick
Weight in pounds per lineal foot	572	582	592	602	612	622	632	642	652
Weight in pounds per lineal foot	548	558	568	578	588	598	608	618	628
Weight in pounds per lineal foot	634	644	654	664	674	684	694	704	714
External Diameter, inches	4½	5	5½	6	6½	7	7	7	7
Weight in pounds per lineal foot	1154	1175	1196	1217	1238	1259	1280	1301	1322
Weight in pounds per lineal foot	1398	1407	1416	1425	1434	1443	1452	1461	1470
Weight in pounds per lineal foot	1600	1707	1804	1901	1997	2094	2191	2288	2385

(Lloyd and Lloyd.)

Internal Diameter, inches		8	9	10	11	12	13	14	15	16	17	18
Weight in pounds per lineal foot	$\left\{ \begin{array}{l} \frac{1}{4} \text{ inch thick} \\ \frac{3}{8} \text{ " } \\ \frac{1}{2} \text{ " } \end{array} \right\}$	22 35 47	25 38 52	28 42 58	30 46 63	33 50 68	35 54 73	38 58 78	41 62 84	43 66 89	46 70 94	48 74 100
Internal Diameter, inches		19	20	21	22	23	24	25	26	27	28	
Weight in pounds per lineal foot	$\left\{ \begin{array}{l} \frac{1}{4} \text{ inch thick} \\ \frac{3}{8} \text{ " } \\ \frac{1}{2} \text{ " } \end{array} \right\}$	51 78 105	54 82 110	56 86 115	59 90 120	62 93 126	64 97 131	67 101 136	69 105 141	72 109 147	75 113 152	
Internal Diameter, inches		29	30	31	32	33	34	35	36	37	38	
Weight in pounds per lineal foot	$\left\{ \begin{array}{l} \frac{1}{4} \text{ inch thick} \\ \frac{3}{8} \text{ " } \\ \frac{1}{2} \text{ " } \end{array} \right\}$	77 117 157	80 121 162	83 125 168	85 129 173	88 133 178	90 137 183	93 140 188	96 144 194	98 148 199	101 152 204	
Internal Diameter, inches		39	40	41	42	43	44	45	46	47	48	
Weight in pounds per lineal foot	$\left\{ \begin{array}{l} \frac{1}{4} \text{ inch thick} \\ \frac{3}{8} \text{ " } \\ \frac{1}{2} \text{ " } \end{array} \right\}$	104 156 210	106 160 215	109 164 220	111 168 225	114 172 230	117 176 236	119 180 241	122 184 246	124 188 251	127 192 257	

STEEL PIPES.**Mild Steel Pipes.**

The Steel Pipe Company shew, in the annexed Tables, the relative thickness and weight of pipes of cast-iron, wrought-iron, and steel, for equal strengths :—

TABLE 115.—RELATIVE THICKNESS OF RIVETED PIPES FOR EQUAL STRENGTH.

Metal.	Cast-Iron.	Wrought-Iron.	Steel.
Weight of 1 square foot, 1 inch thick	37.5 lbs.	40 lbs.	40.8 lbs.
Tenacity per square inch	18,000 lbs.	48,600 lbs.	72,000 lbs.
Relative strength for equal thicknesses	1	2.7	4
Factor of safety	10	6	5
Relative strength due to factor of safety	1	4.5	8
Reduction in strength due to riveted joints	...	50 per cent.	50 per cent.
Relative strength after reduction for riveted joints	1	3.15	5.6
Relative thickness for plates of equal strength	1	.3174	.1785

TABLE 116.—RELATIVE WEIGHT OF PIPES FOR EQUAL STRENGTH.

Metal.	Cast-Iron.	Wrought-Iron.	Steel.
Thickness of plates, weighing 40 lb. per square foot	1.066 inches.	1.00 inch.	.9804 inch.
Relative strength for equal weight	1	2.533	3.673
Relative strength due to factor of safety	1	4.22	7.355
Relative strength after reduction for riveted joints	1	2.955	5.149
Relative weight of plain cylinders of equal strength	1	.3384	.1922
Increase in weight of pipes due to socket and spigot joints	5.8 per cent.	15 per cent.	15 per cent.
Relative weight of pipes of equal strength	1	.3678	.2111

From the first Table it appears that the resistance of riveted steel pipes to bursting is 5.6 times that of cast-iron pipes of equal thickness. The longitudinal seams of the

riveted pipes are double-riveted and are estimated to have 70 per cent of the strength of the solid unriveted plates. The pipes are united in lengths of from 4 feet to 6 feet, with circular seams of single riveting.

The minimum thickness of welded plates is $\frac{1}{8}$ inch.

The weight of steel pipes complete with sockets, spigots, rivets, lap-joints, and asphalt coating $\frac{3}{8}$ inch thick, is one-fourth of that of cast-iron pipes of equal strength. The coating effectually prevents corrosion. The weight of steel pipes complete as above specified, is given by the formula (1).

Weight of Steel Pipes per Lineal Foot.

$$W = .33 d w \quad (1)$$

W = weight per lineal foot,

d = diameter in inches

w = weight of plate or sheet in pounds per square foot.

t = thickness of pipe in inches.

H = working head in feet of water.

Thickness of Pipes and Working Head of Pressure.

$$\left\{ \begin{array}{l} t = .00012 d H \\ H = \end{array} \right. \quad (2)$$

$$\left\{ \begin{array}{l} H = .00012 d \\ t = \end{array} \right. \quad (3)$$

$$\left\{ \begin{array}{l} t = .000025 d H \\ H = \end{array} \right. \quad (4)$$

$$\left\{ \begin{array}{l} H = .000025 d \\ t = \end{array} \right. \quad (5)$$

A 12-inch riveted steel pipe, 8 feet 7 inches long, $\frac{1}{8}$ inch thick, was tested under a bursting pressure of 766 lbs. per square inch. It leaked slightly at one of the rivets, and a portion of the caulking slightly yielded. No other sign of damage was visible. The longitudinal lap-joints had $1\frac{1}{8}$ inches of lap, with $\frac{1}{2}$ -inch rivets at $1\frac{1}{8}$ inches of pitch. It was fitted at each end with a circular flange $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{4}$ -inch thick. The ultimate tensile strength of the metal was 34 tons per square inch. The stress on the metal was at the rate of $766 \times 12 = 9120$ lbs. per lineal inch, or $(9120 \div 1 = 9120 \div 168 = 54.280$ lbs., or 16.3 tons per square inch of section of both sides together. This is about equal to 70 per cent. of the ultimate resistance, or 16.8 tons per square inch, the strength at the joint, showing that the calculated ultimate resistance is corroborated by the results of the test.

TABLE 122.—ROLLED IRON JOISTS
(Measures Brothers & Co.)

Reference Number	Sectional Dimensions Depth × Width	Thickness of		Weight per Lineal Foot	Stock Lengths
		Web.	Flanges (average).		
	Inches.	Inch.	Inch	Pounds.	Feet.
1	19 $\frac{3}{4}$ × 7 $\frac{1}{4}$	1 $\frac{3}{16}$ <i>b</i>	1 $\frac{1}{16}$	100	16 to 40
2	17 $\frac{3}{4}$ × 6 $\frac{1}{4}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	82	16 to 40
3	16 × 6	1 $\frac{1}{16}$	1 $\frac{1}{16}$	62	8 to 40
4	14 × 6	1 $\frac{1}{16}$ <i>b</i>	1 $\frac{1}{16}$	60	8 to 40
5	12 × 7 $\frac{1}{4}$	.	.	72	16 to 36
6	12 × 6	1 $\frac{1}{16}$	1 $\frac{1}{16}$	56	6 to 40
7	12 × 5	1 $\frac{1}{16}$	1 $\frac{1}{16}$	42	6 to 40
8	10 × 6	1 $\frac{1}{16}$	1 $\frac{1}{16}$	56	7 to 36
9	10 × 5	1 $\frac{1}{16}$	1 $\frac{1}{16}$	36	6 to 40
10	10 × 4 $\frac{1}{2}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	32	6 to 36
11	8 $\frac{1}{2}$ × 6	...	...	42	10 to 36
12	9 $\frac{1}{2}$ × 4 $\frac{1}{2}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	29	6 to 40
13	9 $\frac{1}{4}$ × 3 $\frac{3}{4}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	24	6 to 40
14	8 × 6	1 $\frac{1}{16}$	1 $\frac{1}{16}$	34	6 to 30
15	8 × 5	1 $\frac{1}{16}$	1 $\frac{1}{16}$	29	5 to 40
16	8 × 4	1 $\frac{1}{16}$	1 $\frac{1}{16}$	22	5 to 36
17	7 × 3 $\frac{3}{4}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	20	5 to 40
18	6 × 5	1 $\frac{1}{16}$	1 $\frac{1}{16}$	29	5 to 36
19	6 $\frac{1}{4}$ × 3 $\frac{3}{4}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	16	5 to 40
20	5 × 4 $\frac{1}{2}$	1 $\frac{1}{16}$ <i>b</i>	1 $\frac{1}{16}$	23	5 to 36
21	4 $\frac{3}{4}$ × 3	1 $\frac{1}{16}$	1 $\frac{1}{16}$	13	5 to 36
22	4 × 3	1 $\frac{1}{16}$	1 $\frac{1}{16}$	12	5 to 30
23	3 × 3	1 $\frac{1}{16}$ <i>b</i>	1 $\frac{1}{16}$ <i>b</i>	10	5 to 36
24	8 × 2 $\frac{1}{4}$	1 $\frac{1}{16}$ <i>b</i>	1 $\frac{1}{16}$ <i>b</i>	15	6 to 30
25	7 × 2 $\frac{1}{4}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	14	6 to 30
26	6 $\frac{1}{4}$ × 2	1 $\frac{1}{16}$	1 $\frac{1}{16}$	11	5 to 30
27	4 $\frac{3}{4}$ × 1 $\frac{3}{4}$	1 $\frac{1}{16}$ <i>f</i>	1 $\frac{1}{16}$ <i>f</i>	8	5 to 26
28	4 × 1 $\frac{3}{4}$	1 $\frac{1}{16}$ <i>f</i>	1 $\frac{1}{16}$ <i>f</i>	7	5 to 26
29	3 × 1 $\frac{3}{4}$	1 $\frac{1}{16}$	1 $\frac{1}{16}$	5	5 to 26

b — bare; *f* — full.

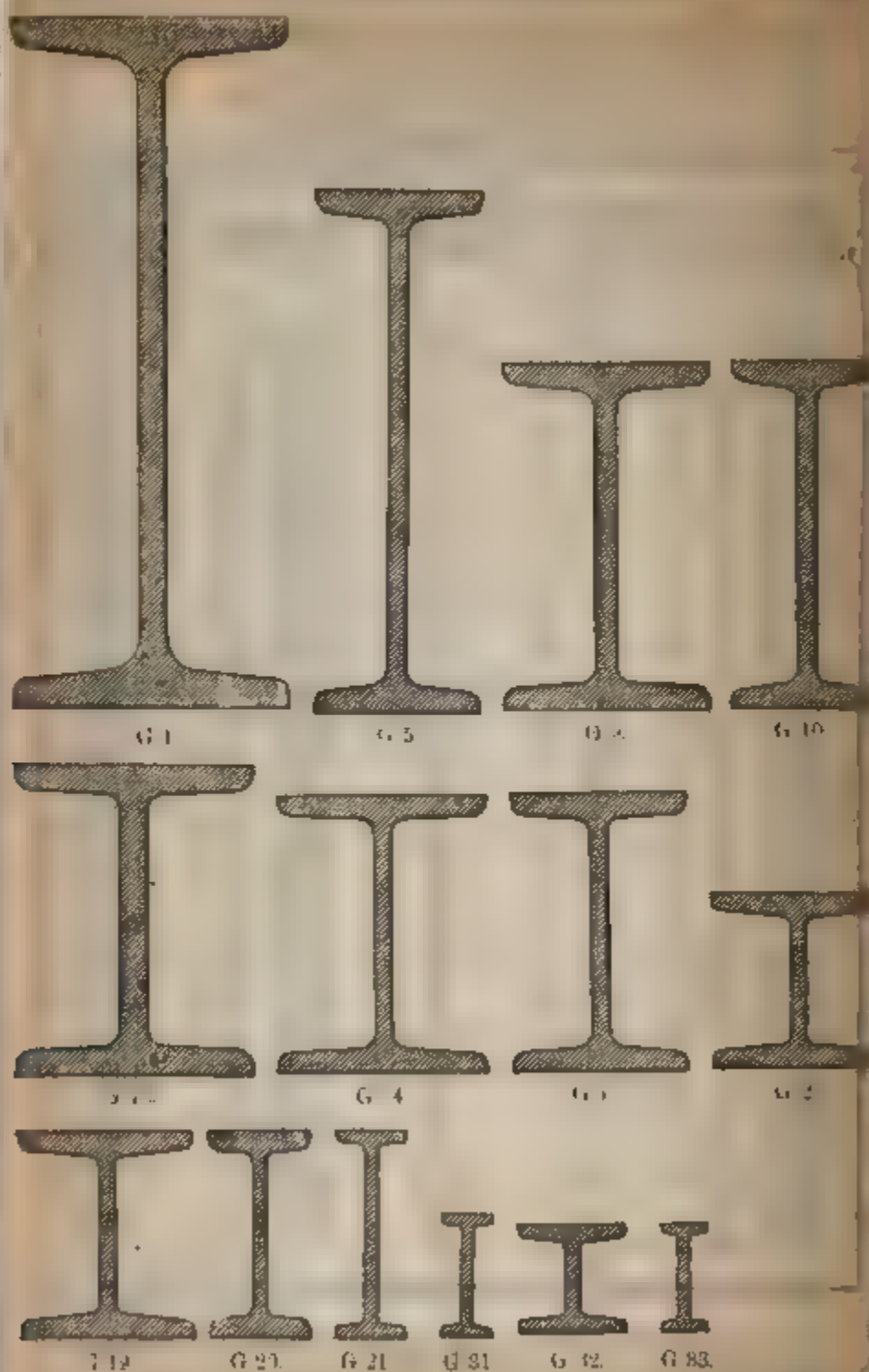
Note.—For Safe Loads, see Table 121.

TABLE 129.—ROLLED IRON JOISTS CALCULATED BREAKING LOAD AT THE CENTRE.

(Butterley Iron Company.)

Sectional Dimensions, Depth x Width.	Minimum Thickness of Web.	Average Thickness of Flanges.	Weight per Linear Foot.	Coefficient of Transverse Strength: Loaded at the Middle.
Inches	Inch.	Inch.	Pounds.	
20 x 10	$\frac{13}{16}$	$1\frac{1}{4}$	140 to 144	20.312
19 $\frac{1}{2}$ x 6 $\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	69 to 70	8.700
18 x 6 $\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	67 to 70	7.704
16 x 6 $\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	63 to 66	6.696
16 x 5 $\frac{1}{2}$	$\frac{11}{16}$	1	69 to 72	7.644
15 x 7 $\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{8}$	57 to 60	6.764
14 x 6 $\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	59 to 62	5.544
12 x 6 $\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	59 to 62	5.044
12 x 6	$\frac{3}{8}$	$\frac{3}{4}$	67 to 77	6.048
12 x 5	$\frac{1}{2}$	$\frac{13}{16}$	46 to 50	4.069
10 $\frac{1}{2}$ x 5 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	38 to 41	2.700
10 x 5	$\frac{1}{2}$	$\frac{5}{8}$	36 to 40	2.564
9 x 5 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	42 to 45	2.902
9 x 4 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	33 to 37	2.144
8 $\frac{1}{2}$ x 4	$\frac{1}{2}$	$\frac{3}{4}$	33 to 36	2.100
8 x 4 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	28 to 30	1.748
8 x 4	$\frac{13}{16}$	$\frac{7}{8}$	40 to 42	2.340
8 x 2 $\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{4}$	19 to 21	1.194
7 $\frac{1}{4}$ x 2 $\frac{3}{4}$	$\frac{1}{2}$	$\frac{7}{16}$	19 to 21	.807
7 x 3 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	23 to 25	1.144
6 $\frac{3}{8}$ x 3 $\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	18 to 20	.846
6 $\frac{1}{4}$ x 2 $\frac{7}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	18 to 20	.825
6 x 6	$\frac{1}{2}$	$\frac{9}{16}$	30 to 32	1.512
6 x 5	$\frac{7}{16}$	$\frac{3}{8}$	26 to 28	1.245
6 x 4	$\frac{1}{2}$	$\frac{9}{16}$	28 to 25	1.094
5 $\frac{7}{8}$ x 5	$\frac{1}{2}$	$\frac{1}{2}$	27 to 29	1.117
5 $\frac{1}{2}$ x 1 $\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	11 to 13	.375
5 x 1 $\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	9 to 11	.334
4 $\frac{1}{2}$ x 1	$\frac{3}{8}$	$\frac{1}{2}$	18 to 18	.560
4 $\frac{1}{4}$ x 1 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$	7 to 9	.251
3 x 1 $\frac{1}{8}$	$\frac{5}{32}$	$\frac{1}{4}$	8 to 1	.60

Use of the Table. Divide the number in the last column by the span in inches, the quotient is the breaking load in tons at the centre.



Figs. 19-32. Ruled Steel Joists Table 124 (Burman, Long & Co.) Scale 1/8"

TABLE 124.—ROLLED STEEL JOISTS (Dorman, Long, & Co.).

Reference Number.	Normal Dimensions. Depth × Width.		Actual Dimensions. Depth × Width.		Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
									Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inches.	Inch.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 1 +	20 × 8	20 × 8-26	.76	.97	29-67	100	1297-84	973-38	778-70		
G 1 -	20 × 8	20 × 8-18	.68	.97	28-24	95	1261-81	946-36	757-09		
G 1 +	20 × 8	20 × 8-11	.61	.97	26-78	90	1226-73	920-05	736-04		
G 2 +	18 × 7	18 × 7-11	.81	.94	26-46	90	992-76	744-13	595-30		
G 2 -	18 × 7	18 × 7-10	.71	.94	24-67	84	954-16	715-62	572-49		
G 2 +	18 × 7	18 × 6-90	.61	.94	22-88	78	915-76	686-82	549-45		
G 3 +	16 × 6	16 × 6-12	.71	.82	20-18	68	669-60	502-2	401-76		
G 3 -	16 × 6	16 × 6-06	.64	.82	19-15	64-5	649-87	487-41	389-92		
G 3 +	16 × 6	16 × 5-95	.54	.82	17-51	59	618-93	464-19	371-35		
G 4 +	15 × 6	15 × 6-17	.79	.81	19-34	65	629-26	471-95	377-56		
G 4 -	15 × 6	15 × 6-09	.72	.81	18-15	61	608-2	456-15	364-90		
G 4 +	15 × 6	15 × 6-01	.64	.81	16-96	57	587-13	440-35	352-28		
G 5 +	15 × 5	15 × 5-26	.70	.80	17-85	60	536-82	426-61	322-10		
G 5 -	15 × 5	15 × 5-16	.60	.80	16-36	55	510-42	382-81	306-25		
G 5 +	15 × 5	15 × 5-06	.50	.80	14-88	50	483-75	362-81	290-25		
G 6 +	14 × 6	14 × 6-05	.67	.81	18-15	61	532-37	406-77	325-42		
G 6 -	14 × 6	14 × 5-96	.59	.81	16-96	57	511-51	391-97	313-57		
G 6 +	14 × 6	14 × 5-87	.5	.81	15-76	53	502-41	376-81	301-45		
G 7 +	12 × 6	12 × 6-23	.73	.87	18-45	62	479-13	359-34	287-47		

TABLE 124.—ROLLED STEEL JOISTS (continued).

Reference Number	Nominal Dimensions, Depth x Width, Inches	Actual Dimensions, Depth x Width, Inches	Thickness of Web, Inch	Metal Flanges 11 inches or less of Flanges, Inch	Metal Flanges more than 11 inches, Inch	Weight per Lineal Foot, Pounds	Distributed Load for One Foot Span			
							Factor 3.	Factor 4.	Factor 5.	Factor 6.
No.	Inches	Inches	Inches	Inches	Inches	Pounds	Tons.	Tons.	Tons.	Tons.
120	6 X 8	5.9 X 7.9	.29	.5	4.46	15	61.07	45.8	36.66	30.44
121	6 X 8	5.9 X 7.9	.47	.38	4.76	14	44.97	33.67	26.44	21.94
122	6 X 8	5.9 X 7.9	.30	.38	3.65	12.25	40.57	30.43	24.34	20.24
123	6 X 8	5.9 X 7.9	.34	.38	3.12	10.5	37.07	27.8	22.24	18.49
124	6 X 8	5.9 X 7.9	.42	.38	3.57	12	36.66	27.49	21.94	18.49
125	6 X 8	5.9 X 7.9	.46	.38	3.27	11	34.69	26.01	20.81	17.68
126	6 X 8	5.9 X 7.9	.31	.38	2.97	10	32.72	24.54	19.68	16.71
127	6 X 8	5.9 X 7.9	.44	.38	3.33	28	91.18	68.38	54.71	45.71
128	6 X 8	5.9 X 7.9	.40	.38	7.58	26.5	84.74	65.05	52.04	43.32
129	6 X 8	5.9 X 7.9	.33	.38	6.82	28	82.2	61.65	49.32	40.90
130	6 X 8	5.9 X 7.9	.42	.38	7.74	26	83.17	62.38	49.90	41.68
131	6 X 8	5.9 X 7.9	.43	.38	7.07	28.75	77.72	58.29	46.68	38.12
132	6 X 8	5.9 X 7.9	.35	.38	6.89	21.5	75.20	56.4	45.12	36.09
133	6 X 8	5.9 X 7.9	.5	.46	5.06	17	51.83	38.86	31.09	25.31
134	6 X 8	5.9 X 7.9	.4	.46	4.64	15.25	48.85	36.64	29.31	24.46
135	6 X 8	5.9 X 7.9	.3	.46	4.02	19.5	45.77	34.83	27.46	22.7
136	6 X 8	5.9 X 7.9	.42	.35	2.98	10	25.46	19.09	15.27	12.7
137	6 X 8	5.9 X 7.9	.37	.35	2.76	9.25	24.20	18.15	14.77	12.7
138	6 X 8	5.9 X 7.9	.32	.35	2.63	8.5	22.95	17.21	13.77	11.77
139	6 X 8	5.9 X 7.9	.57	.4	4.76	16	44.32	33.24	26.60	22.60

TABLE 124.—ROLLED STEEL JOINTS (*continued*).

Reference Number	Normal Dimensions. Depth x Width.	Actual Dimensions. Depth x Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area	Weight per Lineal Foot.	Distributed Load for One Foot Span.			
							Factor 3.	Factor 4.	Factor 5.	
	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.	
G 27	48 x 3	46.2 x 3.17	.42	.4	4.17	14	41.15	30.79	24.63	
G 27	48 x 3	46.2 x 3.04	.29	.4	3.77	12	37.78	28.34	22.67	
G 28	44 x 3	44 x 3.23	.48	.407	4.16	14	34.93	26.2	20.96	
G 28	44 x 3	44 x 3.14	.39	.407	3.79	12.75	33.13	24.85	19.88	
G 28	44 x 3	44 x 3.04	.3	.407	3.42	11.5	31.41	23.55	18.84	
G 29	44 x 3	44 x 3.18	.48	.35	2.97	10	21.57	16.18	12.94	
G 29	44 x 3	44 x 3.07	.37	.35	2.53	8.5	19.50	14.6	11.70	
G 29	44 x 3	44 x 3.06	.26	.35	2.08	9	17.36	13.02	10.42	
G 30	34 x 3	35 x 3.14	.45	.30	3.72	12.5	27.64	20.72	16.59	
G 30	34 x 3	35 x 2.99	.30	.30	3.20	10.75	25.46	19.1	15.27	
G 30	34 x 3	35 x 2.84	.15	.30	2.68	9	23.29	17.47	13.98	
G 31	34 x 3	35 x 3.08	.37	.30	2.68	9	13.58	10.19	8.15	
G 31	34 x 3	35 x 3.0	.28	.30	1.78	6	12.35	9.26	7.41	
G 31	34 x 3	35 x 3.0	.20	.30	1.49	5	11.16	8.37	6.69	
G 32	34 x 3	35 x 3.16	.47	.40	3.57	12	22.41	16.81	13.45	
G 32	34 x 3	35 x 2.99	.30	.40	3.06	10.25	20.56	15.42	12.33	
G 32	34 x 3	35 x 2.81	.13	.40	2.53	8.5	16.70	14.03	11.22	
G 33	34 x 3	35 x 3.49	.40	.25	1.75	6	9.20	6.9	5.32	
G 33	34 x 3	35 x 3.4	.31	.25	1.50	5	8.20	6.19	4.95	
G 33	34 x 3	35 x 3.3	.21	.25	1.19	4	7.2	5.40	4.30	

TABLE 122.—ROLLED IRON JOISTS.
(Measures Brothers & Co.)

Reference Number	Sectional Dimensions. Depth × Width.	Thickness of		Weight per Lineal Foot.	Usual Lengths.
		Web.	Flanges (average).		
	Inches.	Inch.	Inch.	Pounds.	Feet.
1	19 $\frac{1}{2}$ × 7 $\frac{1}{2}$	$\frac{1}{2}$ b	1 $\frac{1}{8}$	100	16 to 40
2	17 $\frac{1}{2}$ × 6 $\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	82	16 to 40
3	16 × 6	$\frac{5}{16}$	$\frac{1}{2}$	62	8 to 40
4	14 × 6	$\frac{5}{16}$ $\frac{1}{8}$	$\frac{1}{2}$	60	8 to 40
5	12 × 7 $\frac{1}{2}$	...	...	72	16 to 35
6	12 × 6	$\frac{5}{16}$ $\frac{1}{8}$	$\frac{1}{2}$	56	6 to 40
7	12 × 5	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	42	6 to 40
8	10 × 6	$\frac{1}{2}$	$\frac{1}{2}$	56	7 to 36
9	10 × 5	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	36	6 to 40
10	10 × 4 $\frac{1}{2}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$	32	6 to 30
11	8 $\frac{1}{2}$ × 6	...	...	42	10 to 30
12	9 $\frac{1}{2}$ × 4 $\frac{1}{2}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	29	6 to 40
13	9 $\frac{1}{2}$ × 3 $\frac{3}{4}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	24	6 to 40
14	8 × 6	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$	34	6 to 30
15	8 × 5	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	29	5 to 40
16	8 × 4	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	22	5 to 30
17	7 × 3 $\frac{3}{4}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	20	5 to 40
18	6 × 5	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$	29	5 to 36
19	6 $\frac{1}{2}$ × 3 $\frac{1}{2}$	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	16	5 to 40
20	5 × 4 $\frac{1}{2}$	$\frac{5}{16}$ $\frac{1}{8}$	$\frac{1}{2}$	23	5 to 36
21	4 $\frac{3}{4}$ × 3	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	13	5 to 36
22	4 × 3	$\frac{1}{2}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	12	5 to 30
23	3 × 3	$\frac{3}{16}$ $\frac{1}{8}$	$\frac{1}{2}$ b	10	5 to 30
24	3 × 2 $\frac{1}{2}$	$\frac{3}{16}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	15	6 to 30
25	7 × 2 $\frac{1}{4}$	$\frac{5}{16}$ $\frac{1}{8}$	$\frac{1}{2}$ $\frac{1}{8}$	14	6 to 30
26	6 $\frac{1}{2}$ × 2	$\frac{1}{2}$ f	$\frac{1}{2}$	11	5 to 30
27	4 $\frac{3}{4}$ × 1 $\frac{3}{4}$	$\frac{1}{2}$ f	$\frac{1}{2}$	8	5 to 26
28	4 × 1 $\frac{3}{4}$	$\frac{1}{2}$ f	$\frac{1}{2}$	7	5 to 26
29	3 × 1 $\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{16}$ $\frac{1}{8}$	5	5 to 26

b = bare ; f = full.

Note.—For Safe Loads, see Table 121.

TABLE 129. ROLLED IRON JOISTS CALCULATED BREAKING LOAD AT THE CENTRE.

(Batterley Iron Company.)

Sectional Dimensions. Depth x Width.	Minimum Thickness of Web.	Average Thickness of Flanges.	Weight per Lineal Foot.	Coefficient of Transverse Strength Load at the Middle.
In. x In.	Inch.	Inch.	Pounds	
20 x 10	$1\frac{1}{2}$	$1\frac{1}{4}$	146 to 144	20,312
19 $\frac{1}{2}$ x 6 $\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	69 to 70	8,700
18 x 6 $\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	67 to 70	7,704
16 x 6 $\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	63 to 66	6,690
16 x 5 $\frac{1}{2}$	$\frac{3}{4}$	1	69 to 72	7,644
15 x 5 $\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{8}$	57 to 60	6,704
14 x 6 $\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	59 to 62	5,544
12 x 6 $\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	59 to 62	5,064
12 x 6	$\frac{3}{4}$	1	67 to 77	6,048
12 x 5	$\frac{3}{4}$	$1\frac{1}{16}$	46 to 50	4,060
10 $\frac{1}{2}$ x 5 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	38 to 41	2,700
10 x 5	$\frac{1}{2}$	$\frac{5}{8}$	36 to 40	2,564
9 x 5 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	42 to 45	2,902
9 x 4 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	33 to 37	2,144
8 $\frac{1}{2}$ x 4	$\frac{1}{2}$	$\frac{5}{8}$	33 to 36	2,100
8 x 4 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	28 to 30	1,748
8 x 4	$\frac{1}{2}$	$\frac{5}{8}$	40 to 42	2,840
8 x 2 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	19 to 21	1,194
7 $\frac{1}{2}$ x 2 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	19 to 21	807
7 x 3 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	23 to 25	1,144
6 $\frac{3}{4}$ x 3 $\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	18 to 20	846
6 $\frac{1}{2}$ x 2 $\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	18 to 20	825
6 x 4	$\frac{1}{2}$	$\frac{5}{8}$	30 to 32	1,512
6 x 5	$\frac{1}{2}$	$\frac{5}{8}$	26 to 28	1,245
6 x 4	$\frac{1}{2}$	$\frac{5}{8}$	23 to 25	1,094
5 $\frac{1}{8}$ x 5	$\frac{1}{2}$	$\frac{1}{2}$	27 to 29	1,117
5 $\frac{1}{2}$ x 1 $\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	11 to 13	375
5 x 1 $\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	9 to 11	334
4 $\frac{1}{2}$ x 1	$\frac{1}{2}$	$\frac{1}{2}$	18 to 18	560
4 $\frac{1}{2}$ x 1 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	7 to 9	251
3 x 1 $\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	3 to 4	60

Use of the Table Divide the number in the last column by the span in inches; the quotient is the breaking load in tons at the centre.

FIGS. 33-44.—SECTIONS OF GIRDERS IN TABLE 126.

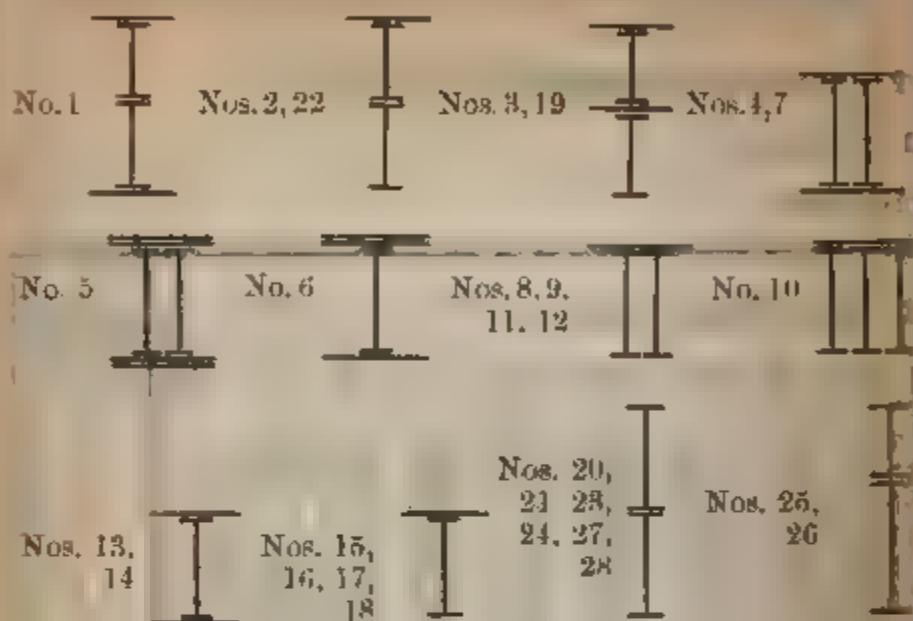
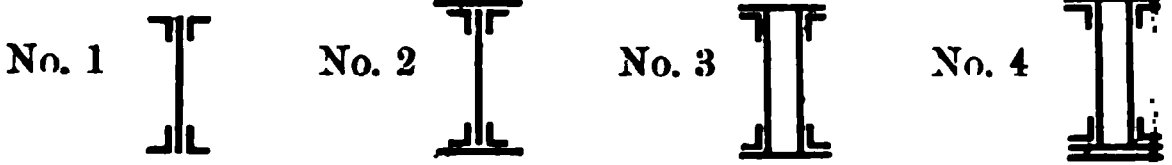


TABLE 127.—ANGLE RIVETTED IRON GIRDERS: ESTIMATE
SAFE PERMANENT DISTRIBUTED LOAD.
(Measures Brothers & Co.)

Refer- ence Num- ber.	Sectional Dimensions, Depth x Width	Weight per Linear Foot.	Clear Span, or Distance between Supports, in Feet.					
			10	12	14	16	18	20
No.	Inches	Pounds.	Tons	Tons	Tons	Tons	Tons	Tons
1	9 x 6 $\frac{3}{8}$	46	13	11	9	8	7	6 $\frac{1}{2}$
2	12 x 9	112	.	39	.	29	26	23
3	13 x 16	154	.	59	...	44	...	35
4	20 x 18	224	...	...	...	...	..	88

Refer- ence Num- ber.	Sectional Dimensions, Depth x Width.	Weight per Linear Foot.	Clear Span, or Distance between Supports, in Feet.					
			22	24	26	30	32	34
No.	Inches.	Pounds.	Tons	Tons	Tons	Tons	Tons	Tons
1	9 x 6 $\frac{3}{8}$	46	.	.	.	...	.	.
2	12 x 9	112	21	19	.	.	.	.
3	13 x 16	154	.	29	27	.	.	.
4	20 x 18	224	.	.	67	58	54	51

FIGS. 45—48.—SECTIONS OF GIRDERS IN TABLE 127.

TABLE 128.—ANGLES (IRON).
(The Butterley Company.)

Reference Number.	Sum of the Sides.	Sectional Dimensions.	Thickness.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inch.	Pounds.
1	14	7 × 7	$\frac{3}{4}$ to $1\frac{1}{4}$	26 to 28
2	$13\frac{1}{2}$	10 × $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	20 to $21\frac{1}{2}$
3	$12\frac{1}{2}$	9 × $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	$17\frac{1}{2}$ to 23
*4	$12\frac{1}{2}$	8 × $4\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	$17\frac{3}{4}$ to $22\frac{1}{2}$
*5	$12\frac{1}{2}$	8 × $4\frac{1}{2}$	$\frac{3}{4}$ only.	...
*6	12	6 × 6	$\frac{5}{8}$ to 1	24 to 27
7	$11\frac{1}{2}$	8 × $3\frac{1}{2}$	$\frac{5}{8}$ to $\frac{3}{4}$	$16\frac{1}{2}$ to 19
*8	11	$5\frac{1}{2}$ × $5\frac{1}{2}$	$\frac{1}{2}$ to $\frac{3}{4}$	$19\frac{1}{2}$ to $25\frac{3}{4}$
*9	$10\frac{1}{2}$	7 × $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	$14\frac{3}{4}$ to $18\frac{1}{2}$
*10	$10\frac{1}{2}$	$6\frac{1}{2}$ × 4	$\frac{1}{2}$ to $\frac{5}{8}$	17 to 23
*11	10	7 × 3	$\frac{3}{8}$ to $\frac{5}{8}$	13 to 16
*12	10	6 × 4	$\frac{1}{2}$ to $\frac{5}{8}$	16 to 23
*13	10	5 × 5	$\frac{1}{2}$ to $\frac{3}{4}$	17 to 24
*14	$9\frac{1}{2}$	6 × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$13\frac{1}{2}$ to 17
*15	9	6 × 3	$\frac{3}{8}$ to $\frac{5}{8}$	$12\frac{1}{2}$ to 17
*16	9	5 × 4	$\frac{3}{8}$ to $\frac{5}{8}$	...
*17	9	$4\frac{1}{2}$ × $4\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$14\frac{1}{2}$ to 21
*18	$8\frac{1}{2}$	$5\frac{1}{2}$ × 3	$\frac{3}{8}$ to $\frac{5}{8}$	$10\frac{1}{4}$ to $16\frac{1}{2}$
*19	$8\frac{1}{2}$	5 × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$10\frac{1}{4}$ to $16\frac{1}{2}$
*20	$8\frac{1}{2}$	$4\frac{1}{4}$ × $4\frac{1}{4}$	$\frac{3}{8}$ to $\frac{5}{8}$	$10\frac{1}{4}$ to $16\frac{1}{2}$
*21	$8\frac{1}{2}$	$4\frac{3}{4}$ × $3\frac{3}{4}$	$\frac{3}{8}$ to $\frac{5}{8}$	$13\frac{1}{2}$ to 18
*22	8	5 × 3	$\frac{3}{8}$ to $\frac{5}{8}$	$9\frac{1}{2}$ to $15\frac{1}{2}$
*23	8	$4\frac{1}{2}$ × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$9\frac{1}{2}$ to $18\frac{1}{2}$
*24	8	4 × 4	$\frac{3}{8}$ to $\frac{5}{8}$	$9\frac{1}{2}$ to 17
*25	$7\frac{1}{2}$	$4\frac{1}{2}$ × 3	$\frac{3}{8}$ to $\frac{5}{8}$	9 to 12
*26	$7\frac{1}{2}$	4 × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	9 to $14\frac{1}{2}$
*27	7	4 × 3	$\frac{5}{16}$ to $\frac{5}{8}$	$8\frac{1}{2}$ to $13\frac{1}{2}$
*28	7	$3\frac{1}{2}$ × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$8\frac{1}{4}$ to $13\frac{1}{4}$
*29	$6\frac{1}{2}$	4 × $2\frac{1}{2}$	$\frac{5}{16}$ to $\frac{5}{8}$	$6\frac{1}{2}$ to $11\frac{1}{2}$
*30	$6\frac{1}{2}$	$3\frac{1}{2}$ × 3	$\frac{5}{16}$ to $\frac{5}{8}$	$6\frac{1}{2}$ to $11\frac{1}{2}$
*31	$6\frac{1}{2}$	$3\frac{1}{4}$ × $3\frac{1}{4}$	$\frac{5}{16}$ to $\frac{5}{8}$	$6\frac{1}{2}$ to $12\frac{1}{4}$
*32	6	4 × 2	$\frac{5}{16}$ to $\frac{1}{2}$	6 to $10\frac{1}{2}$
*33	6	$3\frac{1}{2}$ × $2\frac{1}{2}$	$\frac{5}{16}$ to $1\frac{1}{2}$	6 to $10\frac{1}{2}$
*34	6	3 × 3	$\frac{5}{16}$ to $1\frac{1}{2}$	7 to $11\frac{1}{2}$
*35	$5\frac{1}{2}$	3 × $2\frac{1}{2}$	$\frac{1}{4}$ to $1\frac{1}{2}$	$4\frac{1}{2}$ to 8

TABLE 130.—TEES (IRON) (continued).

Index Number	Size of the Flange and Web	Sectional Dimensions.	Thickness.		Thickness.		Thickness.		Weight per Lineal Foot.
			Flange	Web	Flange	Web	Flange	Web	
No.	Inches.	lbs (Flange) (Web)	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Pounds.
19	*6½	3 5½	1½	1½	1½	1½	1½	1½	10
20	*6	4 2	1½	1½	1½	1½	1½	1½	7
21	*6	3 3	1½	1½	1½	1½	1½	1½	7
22	*5½	3 2½	1½	1½	1½	1½	1½	1½	9
23	*5	3 2	1½	1½	1½	1½	1½	1½	6
24	*5	3 2	1½	1½	1½	1½	1½	1½	7½
25	*5	2½ 1½	1½	1½	1½	1½	1½	1½	3
26	*4½	2½ 1½	1½	1½	1½	1½	1½	1½	3½
27	*4½	2½ 1½	1½	1½	1½	1½	1½	1½	3
28	*4½	2½ 1½	1½	1½	1½	1½	1½	1½	3 to 4½
29	*4	2½ 1½	1½	1½	1½	1½	1½	1½	3
30	*3½	1½ 1½	1½	1½	1½	1½	1½	1½	3
31	*3½	1½ 1½	1½	1½	1½	1½	1½	1½	2
32	*3½	1½ 1½	1½	1½	1½	1½	1½	1½	2
33	*3	1½ 1½	1½	1½	1½	1½	1½	1½	2
34	*2½	1½ 1½	1½	1½	1½	1½	1½	1½	2
35	*2	1½ 1½	1½	1½	1½	1½	1½	1½	2
36	*1½	1½ 1½	1½	1½	1½	1½	1½	1½	2
37	*1½	1½ 1½	1½	1½	1½	1½	1½	1½	2

TABLE 124 - ROLLED STEEL JOISTS (continued).

Reference Number	Normal Dimensions, Depth x Width, Inches.	Actual Dimensions, Depth x Width, Inches.	Thickness of Web, Inch.	Mean Thickness of Flanges, Inch.	Sectional Area, Sq. Inches.	Weight per Linear Foot, Pounds.	Distributed Load for One Foot Span		
							Factor 3	Factor 4	Factor 5
							Tons.	Tons.	Tons.
G 14	8	8	.55	.62	11.8	38	208.61	156.46	125.17
G 14	8	8	.48	.62	10.71	36	202.92	152.19	121.75
G 14	8	8	.40	.62	10.12	34	197.31	147.98	118.39
G 15	8	8	.56	.62	10.12	34	179.52	134.64	107.71
G 15	8	8	.45	.62	9.3	31.25	171.71	128.78	103.02
G 15	8	8	.35	.62	8.48	28.5	163.97	122.98	98.38
G 16	8	8	.59	.66	8.33	28	140.32	105.24	84.19
G 16	8	8	.42	.66	7.44	25	131.86	98.89	79.11
G 16	8	8	.31	.66	6.55	22	123.38	92.53	74.03
G 17	7	7	.49	.46	6.55	22	97.14	72.85	58.28
G 17	7	7	.41	.46	5.95	20	91.20	68.40	54.72
G 17	7	7	.32	.46	5.36	18	86.20	64.65	51.71
G 18	6 25	6 25	.45	.5	5.95	20	79.80	59.85	47.88
G 18	6 25	6 25	.36	.5	5.36	18	75.35	56.52	45.21
G 18	6 25	6 25	.26	.5	4.76	16	70.44	53.20	42.56
G 19	6	6	.64	.5	8.33	28	108.19	81.14	64.91
G 19	6	6	.54	.5	7.73	26	103.93	77.94	62.36
G 19	6	6	.44	.5	7.14	24	99.66	74.74	59.80
G 19	6	6	.39	.5	5.06	17	65.36	48.97	39.18
G 20	6	6	.34	.5	4.76	16	63.21	47.40	37.92

TABLE 124.—ROLLED STEEL JOISTS (continued).

Reference Number.	Normal Dimensions. Depth × Width.	Actual Dimensions. Depth × Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
							Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 20	6 × 3	6 × 2.99	.29	.5	4.46	16	61.07	45.8	36.66
G 21	6 × 2	6 × 2.15	.47	.38	4.16	14	44.07	33.05	26.44
G 21	6 × 2	6 × 2.07	.39	.38	3.65	12.25	40.57	30.43	24.34
G 21	6 × 2	6 × 1.99	.31	.38	3.12	10.5	37.07	27.8	22.24
G 22	5½ × 2	5.5 × 2.1	.42	.38	3.57	12	36.66	27.49	21.99
G 22	5½ × 2	5.5 × 2.04	.36	.38	3.27	11	34.69	26.01	20.81
G 22	5½ × 2	5.5 × 1.99	.31	.38	2.97	10	32.72	24.54	19.63
G 23	5 × 5	5 × 5.2	.64	.5625	8.33	28	91.18	68.38	54.71
G 23	5 × 5	5 × 5.05	.49	.5625	7.58	25.5	86.74	65.05	52.04
G 23	5 × 5	5 × 4.9	.33	.5625	6.82	23	82.2	61.65	49.32
G 24	5 × 4½	5 × 4.62	.62	.58	7.74	26	83.17	62.38	49.90
G 24	5 × 4½	5 × 4.43	.43	.58	7.07	23.75	77.72	58.29	46.63
G 24	5 × 4½	5 × 4.35	.35	.58	6.39	21.5	75.20	56.4	45.12
G 25	5 × 3	5 × 3.25	.5	.46	5.06	17	51.81	38.86	31.03
G 25	5 × 3	5 × 3.15	.4	.46	4.54	15.25	48.85	36.64	29.31
G 25	5 × 3	5 × 3.04	.3	.46	4.02	13.5	45.77	34.33	27.46
G 26	4½ × 1¾	4.75 × 1.82	.42	.35	2.98	10	25.46	19.09	15.27
G 26	4½ × 1¾	4.75 × 1.77	.37	.35	2.76	9.25	24.20	18.15	14.52
G 26	4½ × 1¾	4.75 × 1.72	.32	.35	2.53	8.5	22.95	17.21	13.77
G 27	4½ × 3	4.62 × 3.3	.55	.4	4.76	16	44.32	33.24	26.60

SAFE PERMANENT DISTRIBUTED LOADS

Brothers & Co.).

Safety, 1-4th.

Distances between Supports.									Reference Number.
20	22	24	26	28	30	32	34	36	
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	No.
85.4	77.2	71.2	65.7	60.1	56.9	53.4	50.2	47.4	1
55.8	50.6	46.3	42.8	38.8	36.5	35.0	32.8	31.1	2
19.8	18.3	16.8	15.6	14.7	13.5	...	...	...	3
36.0	50.4	46.2	42.6	39.0	36.9	34.0	32.4	30.9	4
35.0	50.0	45.8	42.5	39.3	36.7	34.5	32.5	30.5	5
48.0	42.9	39.6	37.8	34.3	33.1	29.9	28.1	26.6	6
33.0	29.7	27.6	25.4	23.5	21.7	20.3	19.0	18.0	7
34.0	30.0	28.0	26.0	24.0	22.0	20.0	19.0	18.0	8
19.5	17.7	16.2	15.0	13.8	12.9	12.1	11.4	10.8	9
29.5	26.5	24.3	22.5	20.9	19.0	18.4	17.3	16.3	10
12.6	11.4	10.5	9.6	9.0	8.4	7.8	7.5	6.7	11
9.8	7.5	6.8	6.3	5.8	5.5	...	...	...	12
22.4	20.0	18.6	17.1	15.9	14.7	13.1	14.0	12.4	13
13.0	11.8	10.8	10.0	9.0	8.6	8.1	7.6	7.2	14
15.0	13.7	12.0	11.3	10.4	9.8	9.3	...	...	15
9.4	8.3	7.6	7.2	7.0	6.5	...	...	...	16
6.8	6.2	4.6	4.3	4.0	3.2	...	...	...	17
5.5	5.0	4.5	4.2	3.9	3.0	...	...	...	18
18.4	16.7	15.2	14.1	13.2	12.2	11.6	10.8	10.2	19
14.7	13.3	12.3	11.3	10.5	9.8	...	...	...	20
22.7	20.6	18.9	17.5	16.1	15.0	14.1	13.3	12.6	21
26.6	23.6	21.6	20.0	18.4	17.2	...	...	...	22
37.6	34.1	31.5	29.6	27.4	25.2	3.8	22.4	21.0	23
14.0	12.3	11.6	10.5	9.8	8.9	...	...	...	24
19.0	17.2	15.7	14.6	13.5	12.6	11.8	11.1	10.5	25
14.2	12.9	11.7	10.8	10.1	9.5	8.9	...	7.9	26
9.8	8.7	8.0	7.5	7.0	6.6	...	...	...	27
11.9	10.7	10.0	9.3	8.6	8.0	...	...	...	28

FIGS. 33-44—SECTIONS OF GIRDERS IN TABLE 126.

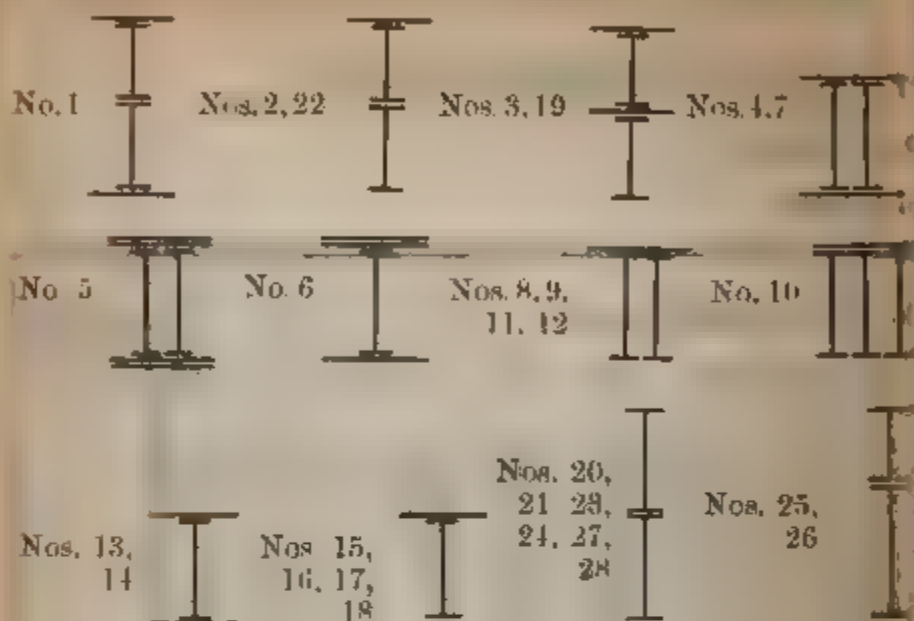


TABLE 127. ANGLE RIVETTED IRON GIRDERS ESTIMATE
SAFE PERMANENT DISTRIBUTED LOAD.
(Measures Brothers & Co.)

Refer- ence Num- ber.	Sectional Dimensions, Depth x Width	Weight per Linear Foot.	Clear Span, or Distance between Supports, in Feet.					
			10	12	14	16	18	20
No.	Feet.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1	9 x 6½	46	13	11	9	8	7	6½
2	12 x 9	112	..	39	..	29	26	23
3	13 x 16	154	..	59	..	44	..	35
4	20 x 18	224	..	..	..	..	..	88

Refer- ence Num- ber.	Sectional Dimensions, Depth x Width	Weight per Linear Foot.	Clear Span, or Distance between Supports, in Feet.					
			22	24	26	30	32	34
No.	Feet.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1	9 x 6½	46	..	..	..	..	..	..
2	12 x 9	112	21	19	..	..	..	..
3	13 x 16	154	..	29	27	..	..	..
4	20 x 18	224	..	..	67	58	54	51

FIGS. 45-48.—SECTIONS OF GIRDERS IN TABLE 127.

TABLE 128.—ANGLES (IRON).
(The Butterley Company.)

Reference Number.	Sum of the Sides.	Sectional Dimensions.	Thickness.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inch.	Pounds.
1	14	7 X 7	$\frac{3}{4}$ to $1\frac{1}{4}$	26 to 28
2	$13\frac{1}{2}$	10 X $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{1}{2}$	20 to $21\frac{1}{2}$
3	$12\frac{1}{2}$	9 X $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{1}{2}$	17 $\frac{1}{2}$ to 23
*4	$12\frac{1}{2}$	8 X $4\frac{1}{2}$	$\frac{7}{16}$ to $\frac{1}{2}$	17 $\frac{1}{2}$ to $22\frac{1}{2}$
*5	$12\frac{1}{2}$	8 X $4\frac{1}{2}$	$\frac{3}{4}$ only.	...
*6	12	6 X 6	to 1	24 to 27
7	$11\frac{1}{2}$	8 X $3\frac{1}{2}$	to $\frac{1}{2}$	16 $\frac{1}{2}$ to 19
*8	11	$5\frac{1}{2}$ X $5\frac{1}{2}$	to $\frac{1}{2}$	19 $\frac{1}{2}$ to $25\frac{1}{2}$
*9	$10\frac{1}{2}$	7 X $3\frac{1}{2}$	to $\frac{1}{2}$	14 $\frac{1}{2}$ to $18\frac{1}{2}$
*10	$10\frac{1}{2}$	$6\frac{1}{2}$ X 4	to $\frac{1}{2}$	17 to 23
*11	10	7 X 3	to $\frac{1}{2}$	13 to 16
*12	10	6 X 4	to $\frac{1}{2}$	16 to 23
*13	10	5 X 5	to $\frac{1}{2}$	17 to $24\frac{1}{2}$
*14	$9\frac{1}{2}$	6 X $3\frac{1}{2}$	to $\frac{1}{2}$	13 $\frac{1}{2}$ to 17
*15	9	6 X 3	to $\frac{1}{2}$	12 $\frac{1}{2}$ to 17
*16	9	5 X 4	to $\frac{1}{2}$	...
*17	9	$4\frac{1}{2}$ X $4\frac{1}{2}$	to $\frac{1}{2}$	14 $\frac{1}{2}$ to 21
*18	$8\frac{1}{2}$	$5\frac{1}{2}$ X 3	to $\frac{1}{2}$	10 $\frac{1}{2}$ to $16\frac{1}{2}$
*19	$8\frac{1}{2}$	5 X $3\frac{1}{2}$	to $\frac{1}{2}$	10 $\frac{1}{2}$ to $16\frac{1}{2}$
*20	$8\frac{1}{2}$	$4\frac{1}{2}$ X $4\frac{1}{2}$	to $\frac{1}{2}$	10 $\frac{1}{2}$ to $16\frac{1}{2}$
*21	$8\frac{1}{2}$	$4\frac{1}{2}$ X $3\frac{1}{2}$	to $\frac{1}{2}$	13 $\frac{1}{2}$ to 18
*22	8	5 X 3	to $\frac{1}{2}$	9 $\frac{1}{2}$ to $15\frac{1}{2}$
*23	8	$4\frac{1}{2}$ X $3\frac{1}{2}$	to $\frac{1}{2}$	9 $\frac{1}{2}$ to 18 $\frac{1}{2}$
*24	8	4 X 4	to $\frac{1}{2}$	9 $\frac{1}{2}$ to 17
*25	$7\frac{1}{2}$	$4\frac{1}{2}$ X 3	to $\frac{1}{2}$	9 to 12
*26	$7\frac{1}{2}$	4 X $3\frac{1}{2}$	to $\frac{1}{2}$	9 to $14\frac{1}{2}$
*27	7	4 X 3	to $\frac{1}{2}$	8 $\frac{1}{2}$ to $13\frac{1}{2}$
*28	7	$3\frac{1}{2}$ X $3\frac{1}{2}$	to $\frac{1}{2}$	8 $\frac{1}{2}$ to $13\frac{1}{2}$
*29	$6\frac{1}{2}$	4 X $2\frac{1}{2}$	to $\frac{1}{2}$	6 $\frac{1}{2}$ to $11\frac{1}{2}$
*30	$6\frac{1}{2}$	$3\frac{1}{2}$ X 3	to $\frac{1}{2}$	6 $\frac{1}{2}$ to $11\frac{1}{2}$
*31	$6\frac{1}{2}$	$3\frac{1}{2}$ X $3\frac{1}{2}$	to $\frac{1}{2}$	6 $\frac{1}{2}$ to $12\frac{1}{2}$
*32	6	4 X 2	to $\frac{1}{2}$	6 to $10\frac{1}{2}$
*33	6	$3\frac{1}{2}$ X $2\frac{1}{2}$	to $\frac{1}{2}$	6 to $10\frac{1}{2}$
*34	6	3 X 3	to $\frac{1}{2}$	7 to $11\frac{1}{2}$
*35	$5\frac{1}{2}$	3 X $2\frac{1}{2}$	to $\frac{1}{2}$	$\frac{1}{2}$ to 8

TABLE 126.—IRON JOIST GIRDERS ESTIM.

(Meas.

Feet)

Reference Number	Sectional Dimensions, Depth \times Width.	Weight per Lineal Foot	Clear Span in Feet.				
			10	12	14	16	18
No.	Inches	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.
1	22 $\frac{1}{2}$ \times 12	245	170.0	142.8	122.0	106.8	94.8
2	20 $\frac{1}{2}$ \times 12	160	112.0	93.2	80.0	70.0	62.4
3	18 $\frac{1}{2}$ \times 8	100	69.0	59.6	50.4	45.2	39.6
4	17 \times 14	175	112.0	102.7	79.5	69.3	61.4
5	15 \times 14	216	110.0	91.7	78.6	69.0	61.2
6	14 \times 12	172	91.0	80	68.5	59.8	53.2
7	11 $\frac{3}{8}$ \times 12	130	61.0	55.0	47.0	40.6	36.2
8	12 $\frac{1}{2}$ \times 12	110	72.0	56.0	48.0	41.0	37.0
9	16 $\frac{1}{2}$ \times 12	80	39.0	32.4	27.9	24.3	21.6
10	13 $\frac{1}{2}$ \times 16	130	59.0	49.1	41.9	34.5	32.2
11	9 $\frac{1}{2}$ \times 8	65	25.2	21.0	18.2	15.6	13.8
12	7 $\frac{1}{2}$ \times 9	56	19.7	15.6	14.4	12.1	10.4
13	13 \times 12	90	41.0	38.5	31.8	28.2	24.6
14	11 \times 9	63	25.0	21.6	18.6	16.7	14.6
15	12 \times 8	57	30.0	24.0	21.7	18.7	16.5
16	10 \times 6	44	18.8	15.2	14.8	12.7	10.0
17	9 $\frac{3}{4}$ \times 6	35	13.4	12.1	8.8	8.4	7.6
18	8 $\frac{1}{2}$ \times 6	34	10.7	9.1	7.8	6.8	6.1
19	16 $\frac{1}{2}$ \times 5	78	36.8	30.6	26.2	23.0	20.4
20	18 $\frac{1}{2}$ \times 3 $\frac{3}{4}$	60	29.4	24.0	21.0	18.2	16.2
21	20 \times 5	70	45.4	37.8	32.4	28.4	25.4
22	20 $\frac{1}{2}$ \times 9	84	53.0	43.2	37.2	32.4	28.4
23	24 \times 5	88	75.8	63.1	54.1	47.6	42.4
24	16 \times 4	41	28.0	23.3	20.0	17.2	15.4
25	16 \times 5	67	38.0	31.2	27.1	23.5	21.4
26	14 $\frac{1}{2}$ \times 4 $\frac{1}{2}$	54	28.4	23.4	20.2	17.8	15.4
27	14 \times 3 $\frac{1}{2}$	42	19.6	16.5	14.4	12.3	11.4
28	12 \times 5	60	23.6	20.0	17.5	15.1	13.4

SAFE PERMANENT DISTRIBUTED LOADS

Brothers & Co.).

Safety, 1-4th.

Distances between Supports.

Reference
Number.

20	22	24	26	28	30	32	34	36	No.
Tons	Tons.	Tons.	Tons.	Tons	Tons.	Tons.	Tons.	Tons.	
85.4	77.2	71.2	65.7	60.1	56.9	53.4	50.2	47.4	1
55.8	50.4	46.3	42.8	38.8	36.5	35.0	32.8	31.1	2
19.8	18.3	16.8	15.6	14.7	13.5	...	...	...	3
36.0	50.4	46.2	42.6	39.0	36.9	34.0	32.4	30.9	4
55.0	50.0	45.8	42.5	39.3	36.7	34.5	32.5	30.5	5
48.0	42.9	39.6	37.8	34.3	33.1	29.9	28.1	26.6	6
33.0	29.7	27.6	25.4	23.5	21.7	20.3	19.0	18.0	7
34.0	30.0	28.0	26.0	24.0	22.0	20.0	19.0	18.0	8
19.5	17.7	16.2	15.0	13.8	12.9	12.1	11.4	10.8	9
29.5	26.5	24.3	22.5	20.9	19.0	18.4	17.3	16.3	10
12.6	11.4	10.5	9.6	9.0	8.4	7.8	7.5	6.7	11
9.8	7.5	6.8	6.3	5.8	5.5	...	...	...	12
22.4	20.0	18.6	17.1	15.9	14.7	13.1	14.0	12.4	13
13.0	11.8	10.8	10.0	9.0	8.6	8.1	7.6	7.2	14
15.0	13.7	12.0	11.3	10.4	9.8	9.3	...	...	15
9.4	8.3	7.6	7.2	7.0	6.5	...	...	...	16
6.8	6.2	4.6	4.3	4.0	3.2	...	...	...	17
5.5	5.0	4.5	4.2	3.9	3.0	...	...	...	18
18.4	16.7	15.2	14.1	13.2	12.2	11.6	10.8	10.2	19
14.7	13.3	12.3	11.3	10.5	9.8	...	...	...	20
22.7	20.6	18.9	17.5	16.1	15.0	14.1	13.3	12.6	21
26.6	23.6	21.6	20.0	18.4	17.2	...	...	...	22
37.6	34.1	31.5	29.6	27.4	25.2	23.8	22.4	21.0	23
14.0	12.3	11.6	10.5	9.8	8.9	...	...	...	24
19.0	17.2	15.7	14.6	13.5	12.6	11.8	11.1	10.5	25
14.2	12.9	11.7	10.8	10.1	9.5	8.9	...	7.9	26
9.8	8.7	8.0	7.5	7.0	6.6	...	...	...	27
11.9	10.7	10.0	9.3	8.6	8.0	...	...	...	28

FIGS. 33 +4.—SECTIONS OF GIRDERS IN TABLE 126.

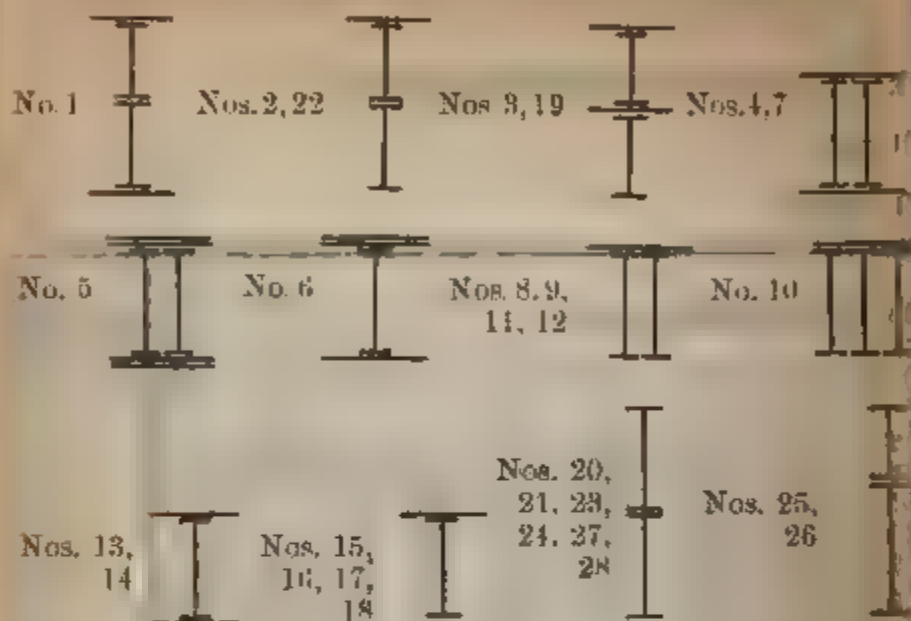


TABLE 127. ANGLE RIVETTED IRON GIRDERS ESTIMATE
SAFE PERMANENT DISTRIBUTED LOAD.
(Masures Brothers & Co.)

Refer- ence Num- ber	Sectional Dimensions, Depth x Width	Weight per Lineal Foot.	Clear Span, or Distance between Supports, in feet.					
			10	12	14	16	18	20
No.	Inches	Pounds.	Tons	Tons.	Tons.	Tons.	Tons	Tons
1	9 x 6½	46	13	11	9	8	7	6½
2	12 x 9	112	..	39	..	29	26	23
3	13 x 16	154	..	59	..	44	..	35
4	20 x 18	224	..	..	..	..	..	88

Refer- ence Num- ber	Sectional Dimensions, Depth x Width	Weight per Lineal Foot	Clear Span, or Distance between Supports, in feet.					
			22	24	26	30	32	34
No.	Inches	Pounds.	Tons	Tons	Tons	Tons	Tons	Tons
1	9 x 6½	46	..	..	..	..	..	..
2	12 x 9	112	21	19	..	..	..	..
3	13 x 16	154	..	29	27	..	..	..
4	20 x 18	224	..	..	67	58	54	51

FIGS. 45—48.—SECTIONS OF GIRDERS IN TABLE 127.

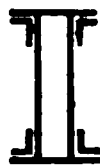
No. 1



No. 2



No. 3



No. 4

TABLE 128.—ANGLES (IRON).
(The Butterley Company.)

Reference Number.	Sum of the Sides.	Sectional Dimensions.	Thickness.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inch.	Pounds.
1	14	7 × 7	$\frac{3}{4}$ to $1\frac{1}{4}$	26 to 28
2	$13\frac{1}{2}$	10 × $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	20 to $21\frac{1}{2}$
3	$12\frac{1}{2}$	9 × $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	$17\frac{1}{2}$ to 23
*4	$12\frac{1}{2}$	8 × $4\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	$17\frac{3}{4}$ to $22\frac{1}{2}$
*5	$12\frac{1}{2}$	8 × $4\frac{1}{2}$	only.	...
*6	12	6 × 6	$\frac{5}{8}$ to 1	24 to 27
7	$11\frac{1}{2}$	8 × $3\frac{1}{2}$	$\frac{5}{8}$ to $\frac{3}{4}$	$16\frac{1}{2}$ to 19
*8	11	$5\frac{1}{2}$ × $5\frac{1}{2}$	$\frac{1}{2}$ to $\frac{3}{4}$	$19\frac{1}{2}$ to $25\frac{1}{2}$
*9	$10\frac{1}{2}$	7 × $3\frac{1}{2}$	$\frac{7}{16}$ to $\frac{5}{8}$	$14\frac{3}{4}$ to $18\frac{1}{2}$
*10	$10\frac{1}{2}$	$6\frac{1}{2}$ × 4	$\frac{1}{2}$ to $\frac{5}{8}$	17 to 23
*11	10	7 × 3	$\frac{3}{8}$ to $\frac{5}{8}$	13 to 16
*12	10	6 × 4	$\frac{1}{2}$ to $\frac{5}{8}$	16 to 23
*13	10	5 × 5	$\frac{1}{2}$ to $\frac{3}{4}$	17 to 24
*14	$9\frac{1}{2}$	6 × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$13\frac{1}{2}$ to 17
*15	9	6 × 3	$\frac{3}{8}$ to $\frac{5}{8}$	$12\frac{1}{2}$ to 17
*16	9	5 × 4	$\frac{3}{8}$ to $\frac{5}{8}$	...
*17	9	$4\frac{1}{2}$ × $4\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$14\frac{1}{2}$ to 21
*18	$8\frac{1}{2}$	$5\frac{1}{2}$ × 3	$\frac{3}{8}$ to $\frac{5}{8}$	$10\frac{1}{4}$ to $16\frac{1}{2}$
*19	$8\frac{1}{2}$	5 × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$10\frac{1}{4}$ to $16\frac{1}{2}$
*20	$8\frac{1}{2}$	$4\frac{1}{4}$ × $4\frac{1}{4}$	$\frac{3}{8}$ to $\frac{5}{8}$	$10\frac{1}{4}$ to $16\frac{1}{2}$
*21	$8\frac{1}{2}$	$4\frac{3}{4}$ × $3\frac{3}{4}$	$\frac{3}{8}$ to $\frac{5}{8}$	$13\frac{1}{2}$ to 18
*22	8	5 × 3	$\frac{3}{8}$ to $\frac{5}{8}$	$9\frac{1}{2}$ to $15\frac{1}{2}$
*23	8	$4\frac{1}{2}$ × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$9\frac{1}{2}$ to $18\frac{1}{2}$
*24	8	4 × 4	$\frac{3}{8}$ to $\frac{5}{8}$	$9\frac{1}{2}$ to 17
*25	$7\frac{1}{2}$	$4\frac{1}{2}$ × 3	$\frac{3}{8}$ to $\frac{5}{8}$	9 to 12
*26	$7\frac{1}{2}$	4 × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	9 to $14\frac{1}{2}$
*27	7	4 × 3	$\frac{5}{16}$ to $\frac{5}{8}$	$8\frac{1}{2}$ to $13\frac{1}{2}$
*28	7	$3\frac{1}{2}$ × $3\frac{1}{2}$	$\frac{3}{8}$ to $\frac{5}{8}$	$8\frac{1}{4}$ to $13\frac{1}{4}$
*29	$6\frac{1}{2}$	4 × $2\frac{1}{2}$	$\frac{5}{16}$ to $\frac{5}{8}$	$6\frac{1}{2}$ to $11\frac{1}{2}$
*30	$6\frac{1}{2}$	$3\frac{1}{2}$ × 3	$\frac{5}{16}$ to $\frac{5}{8}$	$6\frac{1}{2}$ to $11\frac{1}{2}$
*31	$6\frac{1}{2}$	$3\frac{1}{4}$ × $3\frac{1}{4}$	$\frac{5}{16}$ to $\frac{5}{8}$	$6\frac{1}{2}$ to $12\frac{1}{4}$
*32	6	4 × 2	$\frac{5}{16}$ to $\frac{1}{2}$	6 to $10\frac{1}{2}$
*33	6	$3\frac{1}{2}$ × $2\frac{1}{2}$	$\frac{5}{16}$ to $\frac{1}{2}$	6 to $10\frac{1}{2}$
*34	6	3 × 3	$\frac{5}{16}$ to $\frac{1}{2}$	7 to $11\frac{1}{2}$
*35	$5\frac{1}{2}$	3 × $2\frac{1}{2}$	$\frac{1}{4}$ to $\frac{1}{2}$	$4\frac{1}{2}$ to 8

TABLE 130.—TEES (IRON) (continued).

Order Number	Sum of the Flange and Web, Inches	Sectional Dimensions.	Thickness.		Thickness.		Thickness.		Weight per Lineal Foot.
			Flange, Inch.	Web, Inch.	Flange, Inch.	Web, Inch.	Flange, Inch.	Web, Inch.	
No.		Inch. (Flange) (Web)							Pounds.
19	*6½	3½	1	1	1	1	1	1	10
20	*6	2	1	1	1	1	1	1	7
21	*6	3	1	1	1	1	1	1	7
22	*5½	2½	1	1	1	1	1	1	9
23	*5½	3	1	1	1	1	1	1	6
24	*5	3	1	1	1	1	1	1	5½
25	*5	2½	1	1	1	1	1	1	5
26	*4½	2½	1	1	1	1	1	1	3½
27	*4½	2½	1	1	1	1	1	1	3½
28	*4½	2½	1	1	1	1	1	1	3½
29	*4	2	1	1	1	1	1	1	3½
30	*3½	1½	1	1	1	1	1	1	3
31	*3½	1½	1	1	1	1	1	1	3
32	*3½	1½	1	1	1	1	1	1	3
33	*3	1½	1	1	1	1	1	1	3
34	*2½	1	1	1	1	1	1	1	3
35	*2	1	1	1	1	1	1	1	3
36	*1½	1	1	1	1	1	1	1	3
37	*1½	1	1	1	1	1	1	1	3

TABLE 131. BULB BARS (IRON).
(The Butterley Company.)

Order Number.	Width.	Thickness of Bulb.	Thickness of Web.	Weight per Linear Foot
	Inches.	Inches.	Inch.	Pounds.
1	10	$2\frac{1}{2}$ to $2\frac{3}{4}$	$\frac{1}{2}$ to $\frac{3}{4}$	23
2	6	$3\frac{1}{4}$ to $3\frac{3}{4}$	$\frac{1}{2}$ full to $\frac{3}{4}$ full	21 to 24
3	6	$2\frac{1}{4}$ to $2\frac{3}{4}$	$\frac{1}{2}$ to $\frac{3}{4}$	$18\frac{1}{2}$ to 18

Rolled in iron only.

TABLE 132.—BULB TEES OR DECK BEAMS (IRON).
(The Butterley Company.)

Depth (Web).	Width of Flange	Width of Bulb.	Minimum Thickness of Web.	Weight per Linear Foot in Iron
Inches.	Inches.	Inches.	Inch.	Pounds.
16	$6\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{8}$ bare	58 to 62
16	$6\frac{1}{2}$	2 $\frac{1}{2}$	$\frac{1}{8}$ bare	53 to 57
15	$6\frac{1}{2}$	$3\frac{1}{4}$	$\frac{1}{8}$ bare	56 to 60
15	$6\frac{1}{2}$	2 $\frac{1}{4}$	$\frac{1}{8}$ bare	51 to 55
14	$6\frac{1}{2}$	$3\frac{1}{4}$	$\frac{1}{8}$ bare	54 to 58
14	$6\frac{1}{2}$	2 $\frac{1}{4}$	$\frac{1}{8}$ bare	50 to 54
13	$6\frac{1}{2}$	$3\frac{1}{4}$	$\frac{1}{8}$ bare	52 to 56
13	$6\frac{1}{2}$	2 $\frac{1}{4}$	$\frac{1}{8}$ bare	48 to 52
12	$6\frac{1}{2}$	$3\frac{1}{4}$	$\frac{1}{8}$ bare	50 to 54
12	$6\frac{1}{2}$	2 $\frac{1}{4}$	$\frac{1}{8}$ bare	46 to 50
11	$6\frac{1}{2}$	2 $\frac{1}{4}$	$\frac{1}{8}$ bare	45 to 49
†11	6	2 $\frac{1}{4}$	$\frac{1}{8}$ bare	36 to 40
†10	6	2 $\frac{1}{8}$	$\frac{1}{8}$ bare	35 to 39
†10	6	2	$\frac{1}{8}$ bare	32 to 36
†9 $\frac{1}{2}$	$5\frac{1}{2}$	1 $\frac{3}{4}$	$\frac{1}{8}$ bare	31 to 35
†9	$5\frac{1}{2}$	2	$\frac{1}{8}$ bare	32 to 36
†8	$5\frac{1}{2}$	2	$\frac{1}{8}$ bare	35 to 39
†9	$5\frac{1}{4}$	1 $\frac{3}{4}$	$\frac{1}{8}$ bare	29 to 29
†8 $\frac{1}{2}$	$5\frac{1}{4}$	1 $\frac{3}{4}$	$\frac{1}{8}$ bare	25 to 28
†8	$6\frac{1}{4}$	1 $\frac{3}{4}$	$\frac{1}{8}$ bare	31 to 33
†8	$5\frac{1}{4}$	1 $\frac{3}{4}$	$\frac{1}{8}$ bare	27 to 30
†8	5	1 $\frac{3}{4}$	$\frac{1}{8}$ full	22 to 24
†7	5	1 $\frac{3}{4}$	$\frac{1}{8}$ full	23 to 26
†7	5	1 $\frac{5}{8}$	$\frac{1}{8}$ full	19 to 22
†6	5	1 $\frac{1}{2}$	$\frac{1}{8}$ full	19 to 22
*6	$4\frac{1}{2}$	1 $\frac{9}{16}$	$\frac{1}{8}$ full	16 to 18
*6	4	1 $\frac{1}{2}$	$\frac{1}{8}$ full	18 to 20
*6	4	1 $\frac{1}{2}$	$\frac{1}{8}$ full	11 to 16
†	3	1 $\frac{1}{4}$	$\frac{1}{8}$ full	9 to 10

* In iron or steel. † in steel only; the others in iron only.

TABLE 143.—WHITWORTH SCREW BOLTS, ETC. (*continued*)

SCREWS			HEAD AND NUT, HEXAGONAL		
Diameter of Bolt at Screw	Diameter at Bottom of Thread	Threads per Inch	Thickness of Head	Thickness of Nut	Breadth across the Flats
Inches.	Inches.	Threads.	Inches.	Inches.	Inches.
$\frac{1}{4}$...	3	...	...	...
$\frac{1}{2}$...	$2\frac{1}{2}$	...	...	...
$\frac{3}{4}$...	$2\frac{1}{2}$	...	...	...
$\frac{7}{8}$...	$2\frac{1}{2}$	...	...	...
1	...	$2\frac{1}{2}$	...	...	...
$1\frac{1}{4}$...	$2\frac{1}{2}$	...	...	...
$1\frac{1}{2}$...	$2\frac{1}{2}$	...	...	...
$1\frac{3}{4}$...	$2\frac{1}{2}$	...	...	...
2	...	$2\frac{1}{2}$	...	...	...

TABLE 144. SELLERS OR FRANKLIN INSTITUTE STANDARD SCREW BOLTS AND NUTS

Threads triangular in section, heads and nuts hexagonal.

Dia. of Bolt and Screw	Dia. at Bottom of Thread	Width of Flat Space at Base of Thread	Threads per Inch.	Dia. of Bolt and Screw	Dia. at Bottom of Thread	Width of Flat Space at Base of Thread	Threads per Inch.
Inches.	Inches.	Inch.	Threads.	Inches.	Inches.	Inch.	Threads.
$\frac{1}{4}$	.185	.0062	20	$\frac{1}{2}$	1.712	.0277	$4\frac{1}{2}$
$\frac{5}{16}$	.240	.0074	18	$\frac{3}{4}$	1.962	.0277	$4\frac{1}{2}$
$\frac{3}{8}$	.294	.0078	16	$\frac{7}{8}$	2.176	.0312	4
$\frac{7}{16}$	.344	.0080	14	$1\frac{1}{8}$	2.426	.0312	4
$\frac{1}{2}$	.400	.0090	13	1	2.629	.0357	$3\frac{1}{2}$
$\frac{9}{16}$	.454	.0104	12	$1\frac{1}{4}$	2.879	.0357	$3\frac{1}{2}$
$\frac{5}{8}$	.507	.0113	11	$1\frac{3}{8}$	3.100	.0384	$3\frac{1}{2}$
$\frac{3}{4}$	.560	.0125	10	$1\frac{7}{8}$	3.317	.0413	3
$\frac{7}{8}$	.621	.0138	9	2	3.567	.0413	3
1	.687	.0156	8	$2\frac{1}{4}$	3.798	.0435	$2\frac{1}{2}$
$1\frac{1}{8}$	.740	.0178	7	$2\frac{3}{4}$	4.028	.0454	$2\frac{1}{2}$
$1\frac{1}{4}$	.805	.0178	7	$3\frac{1}{4}$	4.256	.0476	$2\frac{1}{2}$
$1\frac{3}{8}$	.860	.0208	6	3	4.480	.0500	$2\frac{1}{2}$
$1\frac{1}{2}$	.924	.0208	6	$3\frac{3}{4}$	4.730	.0500	$2\frac{1}{2}$
$1\frac{5}{8}$	.989	.0227	$5\frac{1}{2}$	4	4.953	.0526	$2\frac{1}{2}$
$1\frac{3}{4}$	1.041	.0250	5	$4\frac{1}{4}$	5.203	.0526	$2\frac{1}{2}$
2	1.166	.0250	5	5	5.423	.0555	$2\frac{1}{2}$

Note 1.—The breadth of heads and nuts, across the flats, equal to $1\frac{1}{2}$ diameters + $\frac{1}{16}$ inch.

Note 2.—The thicknesses of the head and the nut are equal to 1 diameter - $\frac{1}{16}$ inch.

TABLE 145 - WHITWORTH'S STANDARD PITCHES OF
THREAD FOR SCREWED IRON PIPING.

Diameter	Threads per inch.	Diameter	Threads per inch.	Diameter	Threads per inch.
Inches.	Threads.	Inches.	Threads.	Inches.	Threads.
$\frac{1}{8}$	28	$\frac{3}{8}$	14	$1\frac{1}{2}$	11
$\frac{1}{4}$	19	$\frac{1}{2}$	14	$1\frac{3}{4}$	11
$\frac{3}{8}$	19	1	11	2	11
$\frac{1}{2}$	14	$1\frac{1}{4}$	11	above 2	11

TABLE 146. - FRENCH STANDARD BOLTS AND NUTS WITH
HEXAGONAL HEADS AND NUTS
(Annengard).

1. TRIANGULAR THREAD (Equilateral Triangle).

Screw				Head and Nut.			Work- ing Tensile Strength
Diameter of Bolt and Screw		Diameter at Bottom of Thread	Number of Threads per Inch.	Thick- ness of Head.	Thick- ness of Nut.	Breadth across the Flats	
Millimetres.	Inches.	Inches.	Threads.	Inches.	Inches.	Inches.	Lbs.
5	.20	.13	18.1	.24	.20	.55	44
7.5	.30	.22	16	.30	.30	.68	99
10	.39	.31	14.1	.38	.39	.88	178
12.5	.49	.40	12.7	.44	.43	1.04	277
15	.59	.48	11.5	.52	.59	1.20	400
17.5	.69	.58	10.6	.58	.69	1.40	545
20	.79	.65	9.8	.66	.79	1.50	713
22.5	.89	.76	9.1	.72	.89	1.68	902
25	.98	.84	8.5	.80	.98	1.84	1100
30	1.18	1.02	7.5	.94	1.18	2.16	1575
35	1.38	1.20	6.7	1.08	1.38	2.48	1990
40	1.58	1.40	6.0	1.22	1.58	2.80	2400
45	1.77	1.56	5.5	1.37	1.77	3.20	2864
50	1.97	1.74	5.1	1.50	1.97	3.44	3303
55	2.17	1.92	4.7	1.64	2.17	3.76	3745
60	2.36	2.08	4.4	1.74	2.36	4.08	4192
65	2.56	2.26	4.1	1.92	2.56	4.40	4642
70	2.76	2.44	3.8	2.06	2.76	4.70	5097
75	2.95	2.60	3.5	2.20	2.95	5.00	5550
80	3.15	2.78	3.4	2.34	3.15	5.35	6000

TABLE 149.—WEIGHT OF 100 SQUARE-HEAD BOLTS AND NUTS (*continued*).

Length under Head	Diameter of Bolts.						
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2 $\frac{1}{2}$	6 $\frac{3}{4}$	1 $\frac{1}{2}$	2 $\frac{3}{4}$	4 $\frac{1}{2}$	8 $\frac{1}{2}$	13 $\frac{1}{2}$	155
3	6 $\frac{1}{2}$	1 $\frac{1}{4}$	3 $\frac{1}{4}$	5 $\frac{1}{2}$	8 $\frac{1}{4}$	14 $\frac{1}{4}$	200
3 $\frac{1}{2}$	7 $\frac{1}{4}$	1 $\frac{3}{8}$	3 $\frac{3}{4}$	5 $\frac{3}{4}$	9 $\frac{1}{4}$	14 $\frac{3}{4}$	210
4	7 $\frac{1}{2}$	2 $\frac{1}{8}$	3 $\frac{1}{2}$	6 $\frac{1}{2}$	9 $\frac{3}{4}$	15 $\frac{1}{2}$	220
4 $\frac{1}{2}$	8 $\frac{3}{8}$	2 $\frac{1}{4}$	3 $\frac{3}{4}$	6 $\frac{3}{4}$	10 $\frac{1}{2}$	16 $\frac{1}{2}$	230
5	9	2 $\frac{3}{4}$	4 $\frac{1}{2}$	7 $\frac{1}{2}$	10 $\frac{3}{4}$	17 $\frac{1}{2}$	240
5 $\frac{1}{2}$	9 $\frac{1}{2}$	2 $\frac{1}{2}$	4 $\frac{3}{4}$	7 $\frac{3}{4}$	11 $\frac{1}{2}$	18 $\frac{1}{2}$	251
6	10 $\frac{1}{2}$	2 $\frac{1}{2}$	4 $\frac{3}{4}$	7 $\frac{3}{4}$	11 $\frac{1}{2}$	18 $\frac{1}{2}$	262
7	11 $\frac{1}{2}$	2 $\frac{3}{4}$	5 $\frac{1}{4}$	8 $\frac{1}{2}$	13 $\frac{1}{2}$	20 $\frac{1}{2}$	284
8	13 $\frac{1}{4}$	3 $\frac{1}{4}$	6 $\frac{1}{4}$	9 $\frac{1}{2}$	14 $\frac{1}{2}$	22 $\frac{1}{2}$	306
9	14 $\frac{1}{2}$	3 $\frac{3}{4}$	6 $\frac{3}{4}$	10 $\frac{1}{2}$	15 $\frac{1}{2}$	23 $\frac{1}{2}$	328
10	16	4 $\frac{1}{4}$	7 $\frac{1}{4}$	11 $\frac{1}{2}$	17 $\frac{1}{2}$	25 $\frac{1}{2}$	350
11	17 $\frac{1}{2}$	4 $\frac{3}{4}$	7 $\frac{3}{4}$	11 $\frac{3}{4}$	18 $\frac{1}{2}$	26 $\frac{1}{2}$	372
12	18 $\frac{1}{2}$	4 $\frac{3}{4}$	8 $\frac{1}{4}$	12 $\frac{1}{2}$	20 $\frac{1}{2}$	28 $\frac{1}{2}$	398

TABLE 150.—WEIGHT AND TENSILE STRENGTH OF ORDINARY IRON BOLTS.

(Chapman)

Ends Enlarged, or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.
$\frac{1}{8}$	0.114	0.245	5.49	..	...
$\frac{3}{16}$	0.18	0.533	1,230	..	...
$\frac{1}{4}$	0.165	0.983	2,202	..	...
$\frac{5}{16}$	0.258	1.58	3,427	..	...
$\frac{3}{8}$	0.372	2.21	4,950	..	...
$\frac{7}{16}$	0.506	3.00	6,720	..	...
$\frac{1}{2}$	0.651	3.93	8,803	..	...
$\frac{9}{16}$	0.837	4.97	11,133	..	...
$\frac{5}{8}$	1.03	6.14	13,754	..	...
$\frac{11}{16}$	1.25	7.42	16,621	..	...
$\frac{3}{4}$	1.49	8.83	19,779	..	...
$\frac{7}{8}$	1.75	10.4	23,298	..	...

TABLE 150.—WEIGHT AND STRENGTH OF IRON BOLTS (*con.*).

Ends Enlarged, or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.
$\frac{7}{8}$	2.03	12.0	26,880	1.12	3.26
$\frac{15}{16}$	2.33	13.8	30,012	1.20	3.77
1	2.65	15.7	35,168	1.27	4.27
$1\frac{1}{16}$	2.99	16.8	37,632	1.35	4.77
$1\frac{1}{8}$	3.35	18.9	42,336	1.42	5.28
$1\frac{3}{16}$	3.73	21.1	47,264	1.49	5.81
$1\frac{1}{4}$	4.13	23.3	52,192	1.55	6.39
$1\frac{5}{16}$	4.56	25.7	57,568	1.64	7.04
$1\frac{3}{8}$	5.00	28.2	63,168	1.72	7.74
$1\frac{7}{16}$	5.47	30.8	68,992	1.80	8.48
$1\frac{1}{2}$	5.95	33.6	75,264	1.87	9.20
$1\frac{9}{16}$	6.46	36.4	81,536	1.94	9.88
$1\frac{5}{8}$	6.99	39.4	88,256	2.00	10.6
$1\frac{11}{16}$	7.53	42.5	95,200	2.07	11.3
$1\frac{3}{4}$	8.10	45.7	102,368	2.14	12.0
$1\frac{13}{16}$	8.69	49.0	109,760	2.22	12.9
$1\frac{7}{8}$	9.30	52.5	117,600	2.30	13.8
$1\frac{15}{16}$	9.93	56.0	125,440	2.38	14.7
2	10.6	59.7	133,728	2.45	15.7
$2\frac{1}{8}$	12.0	63.8	142,912	2.59	17.5
$2\frac{1}{4}$	13.4	71.6	160,384	2.73	19.5
$2\frac{3}{8}$	14.9	79.7	178,528	2.88	21.6
$2\frac{1}{2}$	16.5	88.4	198,016	3.02	23.9
$2\frac{5}{8}$	18.2	97.4	218,176	3.16	26.1
$2\frac{3}{4}$	20.0	106.9	239,456	3.30	28.5
$2\frac{7}{8}$	21.9	116.8	261,632	3.45	31.1
3	23.8	127.2	284,928	3.60	33.9
$3\frac{1}{4}$	27.9	141.0	315,840	3.86	39.1
$3\frac{1}{2}$	32.4	163.6	366,464	4.12	44.4
$3\frac{3}{4}$	37.2	187.7	420,448	4.41	51.0
4	42.3	213.6	478,464	4.70	57.8
$4\frac{1}{4}$	47.8	227.0	508,480	4.98	65.2
$4\frac{1}{2}$	53.6	254.5	570,080	5.25	72.9
$4\frac{3}{4}$	59.7	283.5	635,040	5.53	80.5
5	66.1	314.2	703,808	5.80	88.1
$5\frac{1}{4}$	72.9	324.7	727,328	6.08	97.0
$5\frac{1}{2}$	80.0	356.4	798,336	6.36	106
$5\frac{3}{4}$	87.5	389.5	872,480	6.63	116
6	95.2	424.1	949,984	6.90	126

TABLE 14B — WATWORTH SCREW BOLTS, ETC. (continued)

Screw.		Head and Nut, Hexagonal			
Diameter of Bolt at Screw	Diameter at Bottom of Thread	Threads per Inch	Thickness of Head,	Thickness of Nut	Breadth across the Flats.
Inches.	Inches.	Threads.	Inches.	Inches.	Inches.
$\frac{1}{8}$	"	3	"	"	"
$\frac{1}{4}$	"	2 $\frac{1}{4}$	"	"	"
$\frac{1}{2}$	"	2 $\frac{1}{2}$	"	"	"
$\frac{3}{4}$	"	2 $\frac{3}{4}$	"	"	"
5 $\frac{1}{8}$	"	2 $\frac{1}{2}$	"	"	"
3 $\frac{1}{2}$	"	2 $\frac{1}{2}$	"	"	"
5 $\frac{1}{4}$	"	2 $\frac{1}{2}$	"	"	"
6	"	2 $\frac{1}{2}$	"	"	"

TABLE 144. WELLS OR FRANKLIN INSTITUTE STANDARD
SCREW BOLTS AND NUTS.

Threads triangular in section, heads and nuts hexagonal

Dia. meter of Bolt and Screw	Dia. meter at Bottom of Thread	Width of Flat Spacing Threads and Base of Thread	Threads per Inch	Dia. meter of Bolt and Screw	Dia. meter at Bottom of Thread	Width of Flat Spacing Threads and Base of Thread	Threads per Inch
Inches.	Inches.	Inches.	Threads.	Inches.	Inches.	Inches.	Threads.
$\frac{1}{4}$	185	0062	20	2	1 712	0277	$4\frac{1}{2}$
$\frac{5}{16}$	210	0074	18	$2\frac{1}{4}$	1 962	0277	$4\frac{1}{2}$
$\frac{3}{8}$	294	0078	16	$2\frac{1}{2}$	2 176	0312	4
$\frac{7}{16}$	344	0089	14	$2\frac{3}{4}$	2 426	0312	4
$\frac{1}{2}$	400	0096	13	3	2 629	0357	$3\frac{1}{2}$
$\frac{9}{16}$	454	0104	12	$3\frac{1}{4}$	2 879	0357	$3\frac{1}{2}$
$\frac{5}{8}$	507	0113	11	$3\frac{3}{4}$	3 100	0384	$3\frac{1}{2}$
$\frac{3}{4}$	620	0125	10	$3\frac{7}{8}$	3 317	0413	3
$\frac{7}{8}$	731	0138	9	4	3 567	0413	3
1	837	0156	8	$4\frac{1}{4}$	3 798	0435	$2\frac{1}{2}$
$1\frac{1}{8}$	940	0178	7	$4\frac{1}{2}$	4 028	0454	$2\frac{1}{2}$
$1\frac{1}{4}$	1 065	0178	7	$4\frac{3}{4}$	4 256	0476	$2\frac{1}{2}$
$1\frac{3}{8}$	1 160	0208	6	5	4 480	0500	$2\frac{1}{2}$
$1\frac{1}{2}$	1 284	0208	6	$5\frac{1}{4}$	4 730	0500	$2\frac{1}{2}$
$1\frac{5}{8}$	1 389	0227	$5\frac{1}{2}$	$5\frac{1}{2}$	4 953	0526	$2\frac{1}{2}$
$1\frac{3}{4}$	1 491	0250	5	$5\frac{3}{4}$	5 203	0526	$2\frac{1}{2}$
$1\frac{7}{8}$	1 616	0250	5	6	5 423	0555	$2\frac{1}{2}$

Note 1:—The breadth of heads and nuts, across the flats, equal to 1½ diameters + ⅛ inch

Fig. 2 - The thicknesses of the head and the nut are equal to 1 diameter - $\frac{1}{4}$ inch

TABLE 145 - WHITWORTH'S STANDARD PITCHES OF
THREAD FOR SCREWED IRON PIPING.

Diameter	Threads per Inch	Diameter	Threads per Inch	Diameter	Threads per Inch
Inches.	Threads.	Inches.	Threads.	Inches.	Threads.
$\frac{1}{8}$	28	$\frac{3}{8}$	14	$\frac{1}{2}$	11
$\frac{1}{4}$	19	$\frac{1}{2}$	14	$\frac{3}{4}$	11
$\frac{3}{8}$	19	1	11	2	11
$\frac{1}{2}$	14	$1\frac{1}{4}$	11	above 2	11

TABLE 146 - FRENCH STANDARD BOLTS AND NUTS WITH
HEXAGONAL HEADS AND NUTS
(Anglemand).

1. TRIANGULAR THREAD (Equilateral Triangle).

Screw				Head and Nut.			Work- ing Tensile Stress.
Diameter of Bolt and Screw		Diameter at Bottom of Thread	Number of Threads per Inch	Thick- ness of Head	Thick- ness of Nut	Breadth across the Flats.	
Milli-metres.	Inches.	Inches.	Threads.	Inches.	Inches.	Inches.	Lbs.
5	.20	.13	18.1	.24	.20	.55	44
7.5	.30	.22	16	.30	.30	.68	99
10	.39	.31	14.1	.38	.39	.88	178
12.5	.49	.39	12.7	.44	.49	1.04	277
15	.59	.48	11.5	.52	.59	1.20	400
17.5	.69	.58	10.6	.58	.69	1.40	545
20	.79	.66	9.8	.66	.79	1.60	713
22.5	.89	.76	9.1	.72	.89	1.68	802
25	.98	.84	8.5	.80	.98	1.84	1000
30	1.18	1.02	7.5	.94	1.18	2.16	1378
35	1.38	1.20	6.7	1.08	1.38	2.48	1999
40	1.58	1.40	6.0	1.22	1.58	2.80	2730
45	1.77	1.56	5.5	1.36	1.77	3.20	3604
50	1.97	1.74	5.1	1.50	1.97	3.44	4603
55	2.17	1.92	4.7	1.64	2.17	3.76	5745
60	2.36	2.08	4.4	1.74	2.36	4.08	7022
65	2.56	2.26	4.1	1.92	2.56	4.40	8442
70	2.76	2.44	3.8	2.06	2.76	4.70	9977
75	2.95	2.60	3.5	2.20	2.95	5.00	11650
80	3.15	2.78	3.4	2.34	3.15	5.30	13470

TABLE 146. —FRENCH STANDARD BOLTS AND NUTS (continued)
2 SQUARE THREAD.

Screw.				Head and Nut.			Working Tensile Strength
Diameter of Bolt and Screw		Depth of Thread.	Number of Threads per Inch.	Thick- ness of Head	Thick- ness of Nut.	Breadth across the Flats.	
Millimetres.	Inches.	Inches	Threads.	Inches.	Inches.	Inches.	Tons.
20	.79	.072	6.57	...	1.82	...	3.2
25	.98	.081	5.97	...	2.01	...	5.1
30	1.18	.098	5.40	...	2.22	...	7.8
35	1.38	.10	4.93	...	2.41	...	9.9
40	1.57	.106	4.53	...	2.63	...	13.0
45	1.77	.114	4.20	...	2.85	...	16.4
50	1.97	.128	3.91	...	3.07	...	20.3
55	2.17	.13	3.65	...	3.30	...	24.5
60	2.36	.14	3.43	...	3.50	...	29.2
65	2.56	.15	3.23	...	3.70	...	34.2
70	2.76	.158	3.06	...	3.92	...	39.7
75	2.95	.166	2.92	...	4.13	...	45.6
80	3.15	.174	2.76	...	4.36	...	51.8
85	3.35	.183	2.63	...	4.58	...	58.5
90	3.54	.192	2.51	...	4.78	...	65.6
95	3.74	.200	2.41	...	5.00	...	73.0
100	3.94	.209	2.31	...	5.22	...	81.0
105	4.13	.220	2.22	...	5.43	...	89.5
110	4.33	.226	2.13	...	5.66	...	98.0
115	4.53	.230	2.06	...	5.87	...	107.1
120	4.72	.234	2.00	...	6.08	...	116.6

TABLE 147.—IRON WASHERS.

Dimensions.		Thick- ness.	Number per Pound.	Dimensions.		Thick- ness.	Number per Pound.
Washer	Bolt Hole.			Washer	Bolt Hole		
Inches.	Inches.	B. W. G.	Washers.	Inches.	Inches.	B. W. G.	Washers.
$\frac{1}{2}$	$\frac{1}{4}$	18	543	$1\frac{1}{2}$	$\frac{3}{16}$	10	170
$\frac{5}{8}$	$\frac{3}{8}$	16	228	2	$\frac{3}{16}$	10	107
$\frac{3}{4}$	$\frac{1}{2}$	16	147	$2\frac{1}{4}$	$\frac{1}{8}$	9	87
$\frac{7}{8}$	$\frac{5}{8}$	16	123	$2\frac{1}{2}$	$1\frac{1}{16}$	9	63
1	$\frac{7}{8}$	14	70.0	$2\frac{3}{4}$	$1\frac{1}{4}$	9	47
$1\frac{1}{4}$	$\frac{1}{2}$	14	50.0	3	$1\frac{1}{4}$	9	37
$1\frac{1}{2}$	$\frac{3}{4}$	12	30.0	$3\frac{1}{4}$	$1\frac{1}{2}$	9	30
$1\frac{3}{4}$	$\frac{7}{8}$	12	25.7				

TABLE 148.—WEIGHTS OF 100 HEXAGONAL HEAD BOLTS AND NUTS.

Length under Head.	Diameter of Bolts.						
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3 $\frac{1}{8}$	7 $\frac{3}{4}$	16 $\frac{3}{4}$	26 $\frac{1}{2}$	...	...	...
1 $\frac{1}{4}$	3 $\frac{1}{2}$	8 $\frac{1}{2}$	17 $\frac{3}{4}$	29 $\frac{1}{2}$	...	...	...
1 $\frac{1}{2}$	3 $\frac{3}{4}$	9 $\frac{1}{2}$	18 $\frac{3}{4}$	31 $\frac{3}{4}$	...	...	...
1 $\frac{3}{4}$	4 $\frac{1}{4}$	10 $\frac{3}{4}$	19 $\frac{3}{4}$	34 $\frac{1}{2}$	...	...	...
2	4 $\frac{3}{4}$	11 $\frac{1}{4}$	20 $\frac{3}{4}$	36 $\frac{3}{4}$	58	115	159
2 $\frac{1}{4}$	5	12 $\frac{1}{4}$	21 $\frac{3}{4}$	39 $\frac{1}{2}$	61 $\frac{1}{2}$	117 $\frac{1}{2}$	164
2 $\frac{1}{2}$	5 $\frac{1}{4}$	13 $\frac{1}{4}$	23 $\frac{3}{4}$	41 $\frac{3}{4}$	65	120	169
2 $\frac{3}{4}$	5 $\frac{3}{4}$	14	24 $\frac{1}{2}$	44 $\frac{1}{2}$	68 $\frac{1}{2}$	122 $\frac{1}{2}$	174
3	6 $\frac{1}{4}$	15	26 $\frac{3}{4}$	46 $\frac{3}{4}$	72	125	179
3 $\frac{1}{4}$	6 $\frac{3}{4}$	16 $\frac{3}{4}$	29 $\frac{3}{4}$	51 $\frac{1}{4}$	78	133	189
4	7 $\frac{1}{4}$	18 $\frac{3}{4}$	32 $\frac{3}{4}$	55 $\frac{1}{4}$	84	141	199
4 $\frac{1}{2}$	8	20 $\frac{3}{4}$	35 $\frac{3}{4}$	60 $\frac{1}{4}$	89 $\frac{1}{2}$	149	209
5	8 $\frac{3}{4}$	22	38 $\frac{3}{4}$	64 $\frac{3}{4}$	95	157	219
5 $\frac{1}{2}$	9 $\frac{1}{4}$	23 $\frac{3}{4}$	41 $\frac{3}{4}$	68 $\frac{3}{4}$	100 $\frac{1}{2}$	165	230
6	10	25 $\frac{3}{4}$	44 $\frac{3}{4}$	72 $\frac{3}{4}$	106	173	241
7	11 $\frac{1}{4}$	28 $\frac{1}{4}$	50 $\frac{3}{4}$	80 $\frac{3}{4}$	118	189	263
8	12 $\frac{3}{4}$	31 $\frac{3}{4}$	56 $\frac{3}{4}$	88 $\frac{3}{4}$	131	205	285
9	14 $\frac{1}{4}$	34 $\frac{3}{4}$	62 $\frac{3}{4}$	96 $\frac{3}{4}$	144	221	307
10	15 $\frac{3}{4}$	38 $\frac{3}{4}$	68 $\frac{3}{4}$	104 $\frac{3}{4}$	158	237	329
11	16 $\frac{3}{4}$	41 $\frac{3}{4}$	74 $\frac{3}{4}$	112 $\frac{3}{4}$	173	253	351
12	18 $\frac{1}{4}$	44 $\frac{3}{4}$	80 $\frac{3}{4}$	121 $\frac{1}{2}$	188	269	372

TABLE 149.—WEIGHTS OF 100 SQUARE-HEAD BOLTS AND NUTS.

Length under Head.	Diameter of Bolts.						
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3 $\frac{1}{4}$	9	20	32	...	...	...
1 $\frac{1}{4}$	3 $\frac{3}{4}$	9 $\frac{3}{4}$	21	34 $\frac{1}{2}$	...	...	...
1 $\frac{1}{2}$	4 $\frac{1}{4}$	10 $\frac{3}{4}$	22	37	...	...	...
1 $\frac{3}{4}$	4 $\frac{3}{4}$	11 $\frac{3}{4}$	23	39 $\frac{1}{4}$	...	...	...
2	5	12 $\frac{3}{4}$	24	42	70	130	180
2 $\frac{1}{4}$	5 $\frac{1}{4}$	13 $\frac{3}{4}$	25 $\frac{1}{4}$	44 $\frac{1}{4}$	73 $\frac{1}{4}$	132 $\frac{1}{4}$	185
2 $\frac{1}{2}$	5 $\frac{3}{4}$	14 $\frac{3}{4}$	27	47	77	135	190

TABLE 149.—WEIGHT OF 100 SQUARE-HEAD BOLTS AND NUTS (*continued*)

Length of Bolt Ends.	Diameter of Bolts.					
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2 $\frac{1}{2}$	6 $\frac{1}{8}$	15 $\frac{1}{2}$	28 $\frac{1}{2}$	49 $\frac{1}{2}$	80 $\frac{1}{2}$	137 $\frac{1}{2}$
3	6 $\frac{1}{2}$	16 $\frac{1}{2}$	30	52	84	140
3 $\frac{1}{2}$	7 $\frac{1}{8}$	18 $\frac{1}{2}$	33	57 $\frac{1}{2}$	90	148
4	7 $\frac{3}{8}$	20	36	61	96	156
4 $\frac{1}{2}$	8 $\frac{1}{8}$	21 $\frac{1}{2}$	39	65 $\frac{1}{2}$	101 $\frac{1}{2}$	164
5	9	23 $\frac{1}{2}$	42	70	107	172
5 $\frac{1}{2}$	9 $\frac{1}{2}$	24 $\frac{1}{2}$	45	74	112 $\frac{1}{2}$	180
6	10 $\frac{1}{8}$	26 $\frac{1}{2}$	48	78	118	188
7	11 $\frac{1}{8}$	29 $\frac{1}{2}$	54	86	130	204
8	13 $\frac{1}{8}$	33	60	94	143	220
9	14 $\frac{1}{2}$	36	66	102	154	236
10	16	40	72	110	170	252
11	17 $\frac{1}{2}$	43	78	118	185	268
12	18 $\frac{1}{2}$	46	84	127	200	284

TABLE 150.—WEIGHT AND TENSILE STRENGTH OF ORDINARY IRON BOLTS.

(Chapman)

Ends Enlarged, or Upset.				Ends not Enlarged.	
Diameter of Shank	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Pounds.	Pounds.	Inches.	Pounds.
$\frac{1}{8}$	0.414	245	549	...	...
$\frac{1}{4}$	0.93	553	1,239	...	...
$\frac{3}{8}$	1.65	983	2,202	35	321
$\frac{1}{2}$	2.78	1,531	3,427	43	452
$\frac{5}{8}$	3.72	2,211	4,955	50	654
$\frac{3}{4}$	5.06	3,001	6,720	58	897
$\frac{7}{8}$	6.51	3,993	8,803	66	1,111
1	8.37	4,971	11,133	73	1,411
1 $\frac{1}{8}$	1.03	6,141	13,754	80	1,671
1 $\frac{1}{4}$	1.25	7,421	16,621	88	2,031
1 $\frac{1}{2}$	1.49	8,831	19,779	96	2,411
1 $\frac{3}{4}$	1.75	10,411	23,296	104	2,811

TABLE 150.—WEIGHT AND STRENGTH OF IRON BOLTS (con.).

Ends Enlarged, or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.
$\frac{7}{16}$	2.03	12.0	26,880	1.12	3.26
$\frac{1}{2}$	2.33	13.8	30,012	1.20	3.77
$\frac{11}{16}$	2.65	15.7	35,168	1.27	4.27
$1\frac{1}{16}$	2.99	16.8	37,632	1.35	4.77
$1\frac{1}{8}$	3.35	18.9	42,346	1.42	5.28
$1\frac{3}{16}$	3.73	21.1	47,264	1.49	5.81
$1\frac{1}{2}$	4.13	23.3	52,192	1.55	6.39
$1\frac{5}{8}$	4.56	25.7	57,568	1.64	7.04
$1\frac{3}{4}$	5.00	28.2	63,168	1.72	7.74
$1\frac{7}{8}$	5.47	30.8	68,992	1.80	8.48
$1\frac{15}{16}$	5.95	33.6	75,264	1.87	9.20
$2\frac{1}{16}$	6.46	36.4	81,536	1.94	9.88
$2\frac{1}{8}$	6.99	39.4	88,256	2.00	10.6
$2\frac{1}{4}$	7.53	42.5	95,200	2.07	11.3
$2\frac{3}{8}$	8.10	45.7	102,368	2.14	12.0
$2\frac{1}{2}$	8.69	49.0	109,760	2.22	12.9
$2\frac{5}{8}$	9.30	52.5	117,600	2.30	13.8
$2\frac{3}{4}$	9.93	56.0	125,440	2.38	14.7
2	10.6	59.7	133,728	2.45	15.7
$2\frac{1}{4}$	12.0	63.8	142,912	2.59	17.5
$2\frac{1}{2}$	13.4	71.6	160,384	2.73	19.5
$2\frac{3}{4}$	14.9	79.7	178,528	2.88	21.6
$2\frac{7}{8}$	16.5	88.4	198,016	3.02	23.9
3	18.2	97.4	218,176	3.16	26.1
$3\frac{1}{8}$	20.0	106.9	239,456	3.31	28.5
$3\frac{1}{4}$	21.9	116.8	261,632	3.45	31.1
$3\frac{3}{8}$	23.8	127.2	284,928	3.60	33.9
$3\frac{1}{2}$	27.9	141.0	315,840	3.86	39.1
$3\frac{3}{4}$	32.4	163.6	366,464	4.12	44.4
$4\frac{1}{8}$	37.2	187.7	420,448	4.41	51.0
$4\frac{1}{4}$	42.3	213.6	478,464	4.70	57.8
$4\frac{3}{8}$	47.8	227.0	508,480	4.98	65.2
$4\frac{1}{2}$	53.6	254.5	570,080	5.25	72.9
$4\frac{3}{4}$	59.7	283.5	635,040	5.53	80.5
5	66.1	314.2	703,808	5.80	88.1
$5\frac{1}{8}$	72.9	324.7	727,328	6.08	97.9
$5\frac{1}{4}$	80.0	356.4	798,336	6.36	106
$5\frac{3}{8}$	87.5	389.5	872,480	6.63	116
6	95.2	424.1	949,984	6.90	126

TABLE 151. NAILS, IRON OR STEEL - SIZES AND WEIGHTS.

Description.	Length			Weight per 1,000.	Description.	Length			Weight per 1,000.
	In.	Lb.	Oz.			In.	Lb.	Oz.	
Spike, do. heads, flat points, wrought . . .	1 $\frac{1}{2}$	4	0		Clasp, fine wrought	3	11	0	
	2	7	4		" "	4	"	"	
	2 $\frac{1}{2}$	12	8		Clasp, fine, cut . . .	2	6	0	
	3	19	12		" "	2 $\frac{1}{2}$	10	0	
	3 $\frac{1}{2}$	27	4		" "	3	16	0	
	4	42	8		Clasp, strong . . .	1 $\frac{1}{2}$	7	0	
	5	89	8		" "	2 $\frac{1}{2}$	10	0	
	6	153	12		" "	2 $\frac{1}{2}$	12	0	
	7	241	0		" "	2 $\frac{1}{2}$	14	0	
Spike, square head, flat points, wrought . . .	5	263	0		" "	3 $\frac{1}{2}$	20	0	
	7	361	12		" "	3 $\frac{1}{2}$	25	0	
	8	478	12		" "	3 $\frac{1}{2}$	32	0	
	9	596	0		" "	4	40	0	
	10	707	8		Clout, counter-sunk, fine wrought . . .	1	4	12	
	12	998	0		" "	1 $\frac{1}{2}$	9	0	
Rose, sharp points, wrought . . .	1	"	"		" "	2	19	0	
Rose, fine flat points, wrought . . .	1 $\frac{1}{2}$	5	0		" "	3	44	0	
" "	1 $\frac{1}{2}$	4	0		Clout, counter-sunk strong, wrought . . .	1 $\frac{1}{2}$	14	8	
" "	2	7	12		" "	2	25	8	
Rose, fine flat points, strong . . .	2 $\frac{1}{2}$	18	8		" "	2 $\frac{1}{2}$	43	8	
" "	3	28	12		" "	3 $\frac{1}{2}$	82	0	
" "	3 $\frac{1}{2}$	40	0		Clout, strong, wrought . . .	1	2	0	
" "	4	54	4		" "	1 $\frac{1}{2}$	3	0	
" "	4 $\frac{1}{2}$	74	8		" "	1 $\frac{1}{2}$	7	0	
" "	5	92	8		" "	2	13	0	
Rose, fine flat points, stamped . . .	1 $\frac{1}{2}$	4	0		Brads, fine, billed, wrought . . .	1	0	4	
" "	1 $\frac{1}{2}$	5	0		" "	1	0	10	
" "	2	7	0		" "	1	1	0	
" "	2 $\frac{1}{2}$	11	0		" "	1 $\frac{1}{2}$	1	8	
" "	3	25	0		" "	1 $\frac{1}{2}$	2	8	
Clasp, bastard, wrought . . .	2	7	0		" "	1 $\frac{1}{2}$	3	0	
" "	2 $\frac{1}{2}$	12	0		" "	2	4	0	
Clasp, fine, wrought . . .	1	1	8		Brads, fine, billed, cut . . .	1	0	3 $\frac{1}{2}$	
" "	1 $\frac{1}{2}$	2	0		" "	1	0	7 $\frac{1}{2}$	
" "	1 $\frac{1}{2}$	3	0		" "	1	1	0	
" "	1 $\frac{1}{2}$	4	0		" "	1 $\frac{1}{2}$	1	8	
" "	2	5	0		" "	1 $\frac{1}{2}$	2	0	
" "	2 $\frac{1}{2}$	7	0		" "	2	3	4	

TABLE 151 — NAILS, IRON OR STEEL, SIZE AND WEIGHTS (continued).

Description.	Length	Weight per 1,000.			Description.	Length	Weight per 1,000.		
		In.	Lb.	Oz.			In.	Lb.	Oz.
Brads, flooring, cut	2½	10	0		Dog, counter-	2	21	4	
"	2½	15	0		sunk, wrought	2½	27	12	
"	3½	20	0		"	3	30	8	
Brads, moulder's,	3½	10	8		Tenter hooks	1½	6	0	
fine, cut	4	12	13		Mop, caulker's,	4½	62	0	
"	4½	15	4		wrought	7	125	0	
"	5	17	10		Slating, wrought,	2			
Tacks, flat head,	3	0	5		galvanised	2			
wrought	½	0	8		Scupper, wrought	3	4	0	
"	½	0	14		"	1	6	4	
Tacks, round	½	1	4		"	1½	10	4	
head, wrought	½				Roofing rivets,				
Tacks, tinned, flat	½	0	5½		wrought with	½			
head, wrought	½	0	9		burr, galvan-	½			
"	½	0	15½		ised, ¼ in. diam.				
Tacks, moulding,	2½	19	12		Glaziers' springs	1	0	4	
wrought	3	32	4		"	1	0	14	
"	4	54	0		Horse shoe	2	7	8	
Tacks, flat head,	3	0	5½		"	2½	7	0	
cut	½	0	8½		"	2½	8	8	
"	½	0	12		"	2½	10	0	
Cooper's flat,	3	1	8		"	1	11	0	
wrought	1	2	4		"	2½	13	8	
"	1½	3	4		Cart wheel tyre	3½	18	8	
					"	4	21	12	

TABLE 152 GALVANISED WROUGHT IRON CYLINDRICAL CISTERNs.
(Gospel Oak Company.)

Capacity (about)	Diameter	Height	Capacity (about)	Diameter	Height.
Gallons.	Inches.	Inches.	Gallons.	Inches.	Inches.
5	11	17½	40	21	33
10	14	21	50	23	35
15	16	22	60	25	36
20	18	24	80	27	42
30	19½	30	100	28	44

TABLE 151.—NAILS, IRON OR STEEL: SIZES AND WEIGHTS.

Description.	Length. In.	Weight per 1,000. Lb. Oz.	Description.	Length. In.	Weight per 1,000. Lb. Oz.
Spike, die heads, flat points,	1½	4 0	Clasp, fine wrought	3	11 0
wrought . . .	2	7 4	" "	4	" "
" " "	2½	12 8	Clasp, fine, cut .	2	6 0
" " "	3	19 12	" "	2½	10 0
" " "	3½	27 4	" "	3	16 0
" " "	4	42 8	Clasp, strong .	1½	7 0
" " "	5	89 8	" "	2½	10 0
" " "	6	158 12	" "	2½	12 0
" " "	7	241 0	" "	2½	14 0
Spike, square head, flat points, wrought	6	268 0	" "	3½	20 0
" " "	7	361 12	" "	3½	25 0
" " "	8	478 12	" "	3½	32 0
" " "	9	596 0	" "	4	40 0
" " "	10	707 8	Clout, counter- sunk, fine.	1	4 12
" " "	12	998 0	wrought .	1½	9 0
Rose, sharp points, wrought	1	2 9	" "	2	19 0
Rose, fine flat points, wrought	1½	5 0	Clout, counter- sunk, strong.	1½	14 8
" " "	1½	4 0	wrought .	2	25 8
" " "	2	7 12	" "	2½	43 8
Rose, fine flat points, strong .	2½	18 8	" "	3½	82 0
" " "	3	28 12	Clout, strong.	1	2 0
" " "	3½	40 0	wrought .	1	3 0
" " "	4	54 4	" "	1½	5 0
" " "	4½	74 8	" "	1½	7 0
" " "	5	92 8	" "	2	13 0
Rose, fine flat points, stamped	1½	4 0	Brads, fine, billed.	¾	0 4
" " "	1½	5 0	wrought .	¾	0 10
" " "	2	7 0	" "	1	1 0
" " "	2½	11 0	" "	1½	1 8
" " "	3	23 0	" "	1½	2 8
Clasp, bastard, wrought .	2	7 0	" "	1½	3 0
Clasp, fine, wrought	2½	12 0	" "	2	4 0
" " "	1	1 8	Brads, fine, billed, cut	¾	0 3½
" " "	1½	2 0	" "	¾	0 7½
" " "	1½	3 0	" "	1	1 0
" " "	1½	4 0	" "	1½	1 8
" " "	2	5 0	" "	1½	2 0
" " "	2½	7 0	" "	2	3 4

TABLE 151 - NAILS, IRON OR STEEL - SIZES AND WEIGHTS (continued).

Description.	Length In.	Weight per 1,000.		Description.	Length In.	Weight per 1,000.	
		Lb.	Oz.			Lb.	Oz.
Brads, flooring, cut	2½	10	0	Dog. counter-	2	21	1
"	2½	15	0	sunk. wrought	2½	27	12
"	3½	20	0	"	3	39	8
Brads, moulder's,	3½	10	8	Tenter hooks	1½	6	0
fine, cut	4	12	13	Mop. caulker's,	4½	62	0
"	4½	15	4	wrought	7	125	0
"	5	17	10	Slating, wrought,	2		
Tacks, flat head,		0	5	galvanised			
wrought		0	8	Scupper, wrought	3	4	0
		0	14	"	1	6	4
Tacks, round		1	4	"	1½	10	4
head, wrought				Roofing rivets,			
Tacks, tinned, flat		0	5½	wrought with			
head, wrought			9	burn, galvan-			
"			15½	ised, 1 in. diam			
Tacks, moulding,	2½	19	12	Roofing sprigs	½	6	1
wrought	3	32	4	"	¾	6	11
"	4	54	0	Horse shoe	2	5	8
Tacks, flat head,		0	5½	"	2½	7	0
cut		0	8½	"	2½	8	8
"		0	12	"	2½	10	0
Cooper's flat		1	8	"	2½	11	0
wrought		2	4	"	2½	13	8
"	1½	3	4	Cart wheel type	3½	18	4
				"	4	218	12

TABLE 152. GALVANISED WROUGHT IRON CYLINDRICAL CISTERNS
(Gospel Oak Company.)

Capacity (about)	Diameter	Height.	Capacity (about)	Diameter	Height
Gallons.	Inches.	Inches.	Gallons.	Inches.	Inches.
5	11	17½	40	21	33
10	14	21	50	23	35
15	16	22	60	25	36
20	18	24	80	27	42
30	19½	30	100	28	48

TABLE 149.—WEIGHT OF 100 SQUARE-HEAD BOLTS AND NUTS (*continued*).

Length inches. Head.	Diameter of Bolts.						
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
2 $\frac{1}{2}$	6 $\frac{1}{4}$	15 $\frac{1}{2}$	28 $\frac{1}{2}$	49 $\frac{1}{2}$	80 $\frac{1}{2}$	137 $\frac{1}{2}$	195
3	6 $\frac{1}{2}$	16 $\frac{1}{2}$	31	52	84	140	200
3 $\frac{1}{2}$	7 $\frac{1}{4}$	18 $\frac{1}{2}$	33	55 $\frac{1}{2}$	90	148	210
4	7 $\frac{3}{4}$	20	36	61	96	156	220
4 $\frac{1}{2}$	8 $\frac{1}{8}$	21 $\frac{1}{8}$	39	65 $\frac{1}{2}$	101 $\frac{1}{2}$	164	230
5	9	23 $\frac{1}{4}$	42	70	107	172	240
5 $\frac{1}{2}$	9 $\frac{1}{2}$	24 $\frac{3}{8}$	45	74	112 $\frac{1}{2}$	180	251
6	10 $\frac{3}{8}$	26 $\frac{1}{2}$	48	78	118	188	262
7	11 $\frac{3}{4}$	29 $\frac{1}{2}$	54	86	130	204	284
8	13 $\frac{1}{4}$	33	60	94	143	220	306
9	14 $\frac{1}{2}$	36	66	102	156	236	328
10	16	40	72	110	170	252	350
11	17 $\frac{1}{2}$	43	78	118	185	268	372
12	18 $\frac{3}{8}$	46	84	127	200	284	398

TABLE 150.—WEIGHT AND TENSILE STRENGTH OF ORDINARY IRON BOLTS.

(Chapman.)

Ends Enlarged or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
inches.	Pounds.	Tons.	Pounds.	inches.	Pounds.
$\frac{1}{8}$	0.14	.245	.549	...	...
$\frac{3}{16}$	.093	.553	1,239	...	...
$\frac{1}{4}$	.165	.983	2,202	...	...
$\frac{5}{16}$	.258	1.53	3,427	.35	321
$\frac{3}{8}$	.372	2.21	4,950	.45	472
$\frac{7}{16}$	.503	3.30	6,720	.50	654
$\frac{1}{2}$	.641	4.93	8,803	.55	897
$\frac{9}{16}$	.837	4.97	11,133	.60	1,141
$\frac{5}{8}$	1.03	6.14	13,754	.65	1,411
$\frac{11}{16}$	1.25	7.42	16,621	.70	1,671
$\frac{3}{4}$	1.49	8.83	19,779	.75	2,031
1	1.75	10.4	23,296	.80	2,411
				.85	2,811

TABLE 150.—WEIGHT AND STRENGTH OF IRON BOLTS (*con.*).

Ends Enlarged; or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.
$\frac{7}{8}$	2.03	12.0	26,880	1.12	3.26
$\frac{15}{16}$	2.33	13.8	30,012	1.20	3.77
1	2.65	15.7	35,168	1.27	4.27
$1\frac{1}{16}$	2.99	16.8	37,632	1.35	4.77
$1\frac{1}{8}$	3.35	18.9	42,336	1.42	5.28
$1\frac{3}{16}$	3.73	21.1	47,264	1.49	5.81
$1\frac{1}{4}$	4.13	23.3	52,192	1.55	6.39
$1\frac{5}{16}$	4.56	25.7	57,568	1.64	7.04
$1\frac{3}{8}$	5.00	28.2	63,168	1.72	7.74
$1\frac{7}{16}$	5.47	30.8	68,992	1.80	8.48
$1\frac{1}{2}$	5.95	33.6	75,264	1.87	9.20
$1\frac{9}{16}$	6.46	36.4	81,536	1.94	9.88
$1\frac{5}{8}$	6.99	39.4	88,256	2.00	10.6
$1\frac{11}{16}$	7.53	42.5	95,200	2.07	11.3
$1\frac{3}{4}$	8.10	45.7	102,368	2.14	12.0
$1\frac{13}{16}$	8.69	49.0	109,760	2.22	12.9
$1\frac{7}{8}$	9.30	52.5	117,600	2.30	13.8
$1\frac{15}{16}$	9.93	56.0	125,440	2.38	14.7
2	10.6	59.7	133,728	2.45	15.7
$2\frac{1}{8}$	12.0	63.8	142,912	2.59	17.5
$2\frac{1}{4}$	13.4	71.6	160,384	2.73	19.5
$2\frac{3}{8}$	14.9	79.7	178,528	2.88	21.6
$2\frac{1}{2}$	16.5	88.4	198,016	3.02	23.9
$2\frac{5}{8}$	18.2	97.4	218,176	3.16	26.1
$2\frac{3}{4}$	20.0	106.9	239,456	3.30	28.5
$2\frac{7}{8}$	21.9	116.8	261,632	3.45	31.1
3	23.8	127.2	284,928	3.60	33.9
$3\frac{1}{4}$	27.9	141.0	315,840	3.86	39.1
$3\frac{1}{2}$	32.4	163.6	366,464	4.12	44.4
$3\frac{3}{4}$	37.2	187.7	420,448	4.41	51.0
4	42.3	213.6	478,464	4.70	57.8
$4\frac{1}{4}$	47.8	227.0	508,480	4.98	65.2
$4\frac{1}{2}$	53.6	254.5	570,080	5.25	72.9
$4\frac{3}{4}$	59.7	283.5	635,040	5.53	80.5
5	66.1	314.2	703,808	5.80	88.1
$5\frac{1}{4}$	72.9	324.7	727,328	6.08	97.0
$5\frac{1}{2}$	80.0	356.4	798,336	6.36	106
$5\frac{3}{4}$	87.5	389.5	872,480	6.63	116
6	95.2	424.1	949,984	6.90	126

TABLE 1st. NAILS, IRON OR STEEL. SIZES AND WEIGHTS.

Description.	Length		Weight per 1000.	Description.	Length		Weight per 1000.
	In.	Lb. Oz.			In.	Lb. Oz.	
Spike, die heads, flat points, wrought	1½	4 0	12	Clasp, fine wrought	3	11 0	12
"	2	7 4		"	4	...	
"	2½	12 8		Clasp, fine, cut	2	6 0	
"	3	19 12		"	2½	10 0	
"	3½	27 4		"	3	16 0	
"	4	42 8		Clasp, strong	1¾	7 0	
"	5	89 8		"	2½	10 0	
"	6	153 12	12	"	2½	12 0	12
"	7	241 0		"	2½	14 0	
Spike, square head, flat points, wrought	7	263 0		"	3½	20 0	
"	8	361 12		"	3½	25 0	
"	9	478 12		"	3½	32 0	
"	10	596 0		"	4	40 0	
"	12	998 0		Clout, counter-sunk, fine wrought	1	4 12	12
Rose, sharp points, wrought	1	2 9	12	"	1½	9 0	
Rose, fine flat points, wrought	1½	5 0		"	2	19 0	
"	2	7 12		Clout, counter-sunk, strong, wrought	3	41 0	
"	2½	18 8		"	1½	14 8	
Rose, fine flat points strong	3	28 12		"	2	25 8	
"	3½	40 0		"	2½	43 8	
"	4	54 4	12	Clout, strong, wrought	3½	82 0	12
"	4½	74 8		"	2	2 0	
"	5	92 8		"	1	3 0	
Rose, fine flat points, stamped	1½	4 0		"	1½	7 0	
"	2	7 0		"	2	13 0	
"	2½	11 0		Brads, fine, siled, wrought	½	0 4	12
"	3	25 0		"	¾	0 10	
Clasp, bastard, wrought	2	7 0	12	"	1	1 0	
Clasp, fine, wrought	2½	12 0		"	1¼	1 8	
"	1	1 8		"	1½	2 8	
"	1¼	2 0		"	1¾	3 0	
"	1½	3 0		"	2	4 0	
"	1¾	4 0		Brads, fine, cut, cut	½	0 3	12
"	2	5 0		"	¾	0 7	
"	2½	7 0	12	"	1	1 0	
"	3	12 0		"	1¼	1 8	
"	3½	17 0		"	1½	2 0	
"	4	22 0		"	2	3 4	
"	4½	27 0		"	2½	4 0	

TABLE 151.—NAILS, IRON OR STEEL—SIZES AND WEIGHTS (*continued*)

Description.	Length In.	Weight per 1,000.		Description.	Length In.	Weight per 1,000.	
		Lb.	Oz.			Lb.	Oz.
Brads, flooring, cut	2½	10	0	Dog, counter-	2	21	1
"	2½	15	0	sunk, wrought	2½	27	12
"	3½	20	0	"	3	39	8
Brads, moulder's,	3½	10	8	Tenter hooks	1½	6	0
fine, cut	4	12	13	Mop, caulker's,	4½	62	0
"	4½	15	4	wrought	7	125	0
"	5	17	10	Slating, wrought,	2	...	
Tacks, flat head,	3	0	5	galvanised	...	...	...
wrought	3	0	8	Scupper, wrought	1	4	0
"	3	0	14	"	1	6	4
Tacks, round	3	1	4	"	1½	10	4
head, wrought	3	1	4	Roofing rivets,	...	...	...
Tacks, tinned, flat	3	0	5½	wrought with	½	...	...
head, wrought	3	0	9	turns, galvan-	...	...	...
"	3	0	10½	ised, 1 in diam	...	...	...
Tacks, moulding,	2½	19	12	Glaziers' springs,	½	0	4
wrought	3	39	4	"	¾	0	4
"	4	54	0	Horse shoe	2	5	8
Tacks, flat head,	3	0	5½	"	2½	7	1
cut	3	0	8½	"	2½	8	8
"	3	0	12	"	2½	10	0
Cooper's flat,	3	1	8	"	2½	11	0
wrought	1	2	4	"	2½	13	8
"	1½	3	4	Cart wheel tyre	3½	187	8
				"	4	218	12

TABLE 152.—GALVANISED WROUGHT IRON CYLINDRICAL CISTERNS.

(Gospel Oak Company)

Capacity (about)	Diameter	Height.	Capacity (about)	Diameter	Height.
Gallons.	Inches.	Inches.	Gallons.	Inches.	Inches.
5	11	17½	40	21	33
10	14	21	50	23	37
15	16	22	60	25	38
20	18	24	80	27	42
30	19½	30	100	28	48

TABLE 154. — CAST IRON CYLINDERS (*continued*).

Inch. Inside Dia. II.	Thickness in Inches.											
	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	
Inch.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	
48	2.6	3.21	3.75	4.30	4.85	5.40	5.96	6.52	7.63	8.77	9.9	
51	2.82	3.4	3.98	4.56	5.14	5.73	6.32	6.91	8.09	9.29	10.5	
54	2.99	3.6	4.21	4.82	5.44	6.06	6.69	7.31	8.57	9.82	11.1	
57	3.15	3.80	4.44	5.09	5.73	6.38	7.05	7.70	9.01	10.4	11.7	
60	3.32	4.00	4.67	5.35	6.03	6.71	7.41	8.10	9.47	10.9	12.3	
63	3.48	4.19	4.90	5.61	6.33	7.04	7.78	8.49	9.93	11.4	12.9	
66	3.64	4.39	5.13	5.88	6.62	7.37	8.14	8.89	10.4	11.9	13.5	
69	3.81	4.59	5.36	6.14	6.92	7.70	8.51	9.28	10.9	12.5	14.1	
72	3.97	4.78	5.59	6.40	7.21	8.03	8.87	9.67	11.3	13.0	14.7	
75	4.14	4.98	5.82	6.66	7.51	8.36	9.24	10.1	11.8	13.5	15.2	
78	4.30	5.18	6.05	6.93	7.81	8.69	9.60	10.5	12.2	14.0	15.8	
81	4.46	5.38	6.28	7.19	8.10	9.02	9.97	10.9	12.7	14.6	16.4	
84	4.63	5.57	6.51	7.45	8.40	9.35	10.3	11.3	13.2	15.1	17.0	
87	4.79	5.77	6.74	7.72	8.69	9.67	10.7	11.6	13.6	15.6	17.6	
90	4.96	5.97	6.97	7.98	8.99	10.0	11.1	12.0	14.1	16.1	18.2	
93	5.12	6.17	7.20	8.24	9.29	10.3	11.4	12.4	14.5	16.7	18.8	
96	5.28	6.36	7.43	8.51	9.58	10.7	11.8	12.8	15.0	17.2	19.4	
99	5.45	6.56	7.65	8.77	9.88	11.0	12.2	13.2	15.5	17.7	20.0	
102	5.61	6.76	7.89	9.03	10.2	11.3	12.5	13.6	15.9	18.2	20.6	
105	5.78	6.95	8.12	9.29	10.5	11.7	12.9	14.0	16.4	18.8	21.2	
108	5.94	7.15	8.36	9.56	10.8	12.1	13.3	14.4	16.8	19.3	21.8	
111	6.11	7.35	8.59	9.82	11.1	12.3	13.6	14.8	17.3	19.8	22.3	
114	6.27	7.55	8.82	10.1	11.4	12.6	14.0	15.2	17.8	20.3	22.9	
117	6.43	7.74	9.05	10.4	11.7	13.0	14.3	15.6	18.2	20.9	23.5	
120	6.59	7.94	9.28	10.6	12.0	13.3	14.7	16.0	18.7	21.4	24.1	

TABLE 155. — CAST-IRON CYLINDERS. WEIGHT BY EXTERNAL DIAMETER.
Length, 1 Foot.

External Diameter	Thickness in Inches.						
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3	9.65	11.0	12.3	14.6	16.6	18.3	19.6
$3\frac{1}{2}$	11.5	13.2	14.7	17.6	20.3	22.6	24.5
4	13.3	15.3	17.2	20.7	24.0	26.9	29.5
$4\frac{1}{2}$	15.2	17.5	19.6	23.8	27.7	31.1	34.4
5	17.0	19.6	22.1	26.9	31.5	35.4	39.3
$5\frac{1}{2}$	18.9	21.8	24.5	29.9	35.2	39.7	44.2
6	20.7	23.9	27.0	33.6	38.9	44.0	49.1
$6\frac{1}{2}$	22.5	26.0	29.5	35.1	42.6	48.3	54.0

TABLE 156. CAST-IRON CYLINDERS (continued)

External Diameter.	Thickness in inches						
	1	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7	24.2	28.2	31.9	39.1	46.4	52.6	58.9
7 $\frac{1}{2}$	26.2	30.3	34.4	42.2	50.1	56.9	63.8
8	28.1	32.5	36.8	45.3	53.8	61.2	68.7
8 $\frac{1}{2}$	29.9	34.6	39.3	48.3	57.5	65.5	73.6
9	31.8	36.8	41.7	51.4	61.3	69.8	78.5
9 $\frac{1}{2}$	33.6	38.9	44.2	54.5	65.0	74.1	83.5
10	35.4	41.1	46.6	57.5	68.7	78.4	88.4
11	39.1	45.4	51.5	63.7	76.0	87.0	98.2
12	42.8	49.7	56.5	69.8	83.4	95.5	108.0
13	46.5	54.0	61.4	75.9	90.7	104.2	117.8
14	50.2	58.3	66.3	82.1	98.0	112.8	127.6
15	53.8	62.6	71.2	88.2	105.4	121.3	137.4
16	57.5	66.9	76.1	94.3	112.7	129.5	147.3
17	61.2	71.1	81.0	100.5	120.0	138.5	157.1
18	64.9	75.4	85.9	106.6	127.4	147.1	166.9
19	68.6	79.7	90.8	112.8	134.7	155.5	176.7
20	72.3	84.0	95.7	118.9	142.0	164.3	186.5
21	75.9	88.3	100.6	125.0	149.4	172.9	196.4
22	79.6	92.6	105.5	131.2	156.7	181.5	206.2
23	83.3	96.9	110.5	137.3	164.0	190.1	215.0
24	87.0	101.2	117.4	143.4	171.4	198.7	225.8
25	90.7	105.5	120.3	149.6	178.7	207.2	235.6
26	94.3	109.8	125.2	155.7	186.1	215.8	245.4
27	98.0	114.1	130.1	161.8	193.4	224.4	255.3
28	101.7	118.4	135.0	168.0	200.7	233.0	265.1
29	105.4	122.7	139.9	174.1	208.1	241.5	274.9
30	109.1	127.0	144.8	180.2	215.4	250.2	284.7
31	112.8	131.3	149.7	186.4	222.7	258.8	294.5
32	116.4	135.6	154.6	192.5	230.1	267.4	304.3
33	120.1	139.9	159.5	198.7	237.5	276.0	314.2
34	123.8	144.2	164.5	204.8	244.8	284.6	324.0
35	127.5	148.5	169.4	210.9	252.2	293.1	333.8
36	131.2	152.7	174.3	217.1	259.5	301.7	343.6
38	138.5	161.3	184.1	229.3	274.3	318.9	363.2
40	145.9	169.9	193.9	241.6	289.0	336.1	382.9
42	153.3	178.5	203.7	253.9	303.7	353.3	402.5
45	161.3	191.2	218.5	272.3	322.8	371.1	432.0
48	175.4	203.8	233.2	290.7	347.9	401.8	461.4
51	186.4	216.5	247.9	305.1	362.0	430.8	490.9
54	197.5	229.2	262.6	327.5	392.1	456.4	520.3
57	208.5	241.8	277.4	345.9	414.2	482.1	549.8
60	219.6	254.5	292.1	364.3	436.3	507.9	579.2

TABLE 156 CAST-IRON CYLINDERS (*continued*).

External Diameter	Thickness in Inches.						
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
63	2.06	2.39	2.74	3.42	4.09	4.77	5.45
66	2.16	2.50	2.87	3.58	4.29	5.00	5.70
69	2.26	2.62	3.00	3.75	4.49	5.23	5.96
72	2.36	2.74	3.14	3.91	4.69	5.46	6.22
75	2.45	2.85	3.27	4.08	4.88	5.69	6.49
78	2.55	2.97	3.40	4.24	5.08	5.92	6.75
81	2.65	3.09	3.53	4.41	5.28	6.15	7.01
84	2.75	3.20	3.66	4.57	5.47	6.38	7.28
90	2.95	3.43	3.92	4.90	5.87	6.84	7.80
96	3.15	3.67	4.19	5.28	6.26	7.30	8.33

External Diameter.	Thickness in Inches.						
	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	2	$2\frac{1}{4}$
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
6	.481	.520	.557	.592	.632	.671	.710
6 $\frac{1}{2}$	.530	.575	.618	.657	.729	.789	.833
7	.579	.630	.678	.723	.805	.876	.930
7 $\frac{1}{2}$	.629	.685	.738	.789	.882	.964	1.04
8	.678	.740	.799	.855	.959	1.05	1.14
8 $\frac{1}{2}$	.727	.794	.859	.921	1.04	1.14	1.25
9	.777	.849	.919	.986	1.13	1.23	1.35
9 $\frac{1}{2}$	.826	.904	.980	1.05	1.19	1.31	1.45
10	.875	.959	1.04	1.12	1.27	1.40	1.55
11	.974	1.07	1.16	1.25	1.42	1.58	1.75
12	1.07	1.18	1.28	1.38	1.57	1.75	1.95
13	1.17	1.29	1.40	1.51	1.73	1.93	2.15
14	1.27	1.40	1.52	1.64	1.88	2.10	2.33
15	1.37	1.51	1.65	1.78	2.03	2.28	2.55
16	1.47	1.62	1.77	1.91	2.19	2.45	2.71
17	1.57	1.73	1.89	2.04	2.34	2.63	2.91
18	1.66	1.84	2.01	2.17	2.49	2.81	3.11
20	1.86	2.06	2.25	2.43	2.80	3.16	3.56
22	2.06	2.27	2.49	2.70	3.11	3.51	3.95
24	2.26	2.49	2.73	2.96	3.41	3.86	4.35
27	2.55	2.82	3.09	3.35	3.87	4.38	4.95
30	2.85	3.15	3.46	3.75	4.33	4.91	5.52
33	3.14	3.48	3.82	4.14	4.79	5.44	6.06
36	3.44	3.81	4.18	4.54	5.25	5.96	6.66
39	3.74	4.14	4.54	4.93	5.72	6.43	7.22

TABLE 156. -CAST-IRON CYLINDERS (*continued*).

External Diameter	Thickness in Inches.						
	1 $\frac{1}{8}$	1 $\frac{1}{4}$	1 $\frac{3}{8}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	2	2 $\frac{1}{2}$
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
42	4.03	4.47	4.90	5.33	6.18	7.01	7.84
45	4.33	4.79	5.20	5.72	6.64	7.54	8.43
48	4.62	5.12	5.62	6.12	7.10	8.07	9.02
51	4.92	5.45	5.98	6.51	7.56	8.59	9.61
54	5.22	5.78	6.35	6.91	8.02	9.12	10.2
57	5.51	6.11	6.73	7.30	8.48	9.64	10.8
60	5.81	6.44	7.07	7.70	8.94	10.2	11.4
<hr/>							
Ft. In.							
5 8	6.10	6.77	7.43	8.09	9.46	10.7	12.0
5 6	6.40	7.09	7.76	8.48	9.86	11.2	12.6
5 9	6.70	7.42	8.15	8.88	10.3	11.8	13.2
6 0	7.00	7.75	8.51	9.27	10.8	12.3	13.8
6 3	7.29	8.08	8.88	9.67	11.2	12.8	14.4
6 6	7.58	8.41	9.24	10.1	11.7	13.3	14.9
6 9	7.88	8.74	9.60	10.5	12.2	13.9	15.5
7 0	8.17	9.07	9.96	10.9	12.7	14.4	16.1
7 6	8.77	9.72	10.7	11.6	13.5	15.4	17.3
8 0	9.36	10.4	11.4	12.4	14.5	16.5	18.5
8 6	9.95	11	12.1	13.2	15.4	17.5	19.7
9 0	10.5	11.7	12.9	14.0	16.3	18.6	20.8
9 6	11.1	12.5	13.6	14.8	17.2	19.6	22.0
10 0	11.7	13.0	14.3	15.6	18.1	20.7	23.2
10 6	12.3	13.7	15.0	16.4	19.1	21.7	24.4
11 0	12.9	14.3	15.7	17.2	20.0	22.8	25.6
11 6	13.5	15.0	16.5	17.9	20.9	23.8	26.7
12 0	14.1	15.6	17.2	18.7	21.8	24.9	27.9
13 0	15.3	16.9	18.6	20.3	23.7	27	30.3
14 0	16.5	18.3	20.1	21.9	25.5	29.1	32.7
15 0	17.7	19.6	21.5	23.5	27.3	31.2	35.0
16 0	18.8	20.9	23.0	25.0	29.2	33.5	37.4
17 0	20.0	22.2	24.4	26.6	31.0	35.4	39.8
18 0	21.2	23.5	25.9	28.2	32.9	37.5	42.2
19 0	22.4	24.8	27.3	29.8	34.7	39.6	44.5
20 0	23.6	26.1	28.8	31.1	36.5	41.7	46.9

TABLE 154. -CAST IRON CYLINDERS (continued).

Inside Diameter	Thickness in Inches											
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1 $\frac{1}{8}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	2	2 $\frac{1}{2}$	3	3 $\frac{1}{2}$	4
Inch	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
48	2 6	3 21	3 75	4 30	4 85	5 40	5 96	6 52	7 63	8 77	9 91	11 05
51	2 82	3 40	3 98	4 56	5 14	5 73	6 32	6 91	8 09	9 29	10 5	11 6
54	2 99	3 60	4 21	4 82	5 44	6 06	6 69	7 31	8 55	9 82	11 1	12 2
57	3 15	3 80	4 44	5 09	5 73	6 38	7 00	7 70	9 01	10 4	11 7	12 9
60	3 32	4 00	4 67	5 35	6 03	6 71	7 41	8 10	9 47	10 9	12 3	13 5
63	3 48	4 19	4 90	5 61	6 33	7 04	7 78	8 49	9 93	11 4	12 9	14 1
66	3 64	4 39	5 13	5 88	6 62	7 37	8 14	8 89	10 4	11 9	13 5	14 7
69	3 81	4 59	5 36	6 14	6 92	7 70	8 51	9 28	10 9	12 5	14 1	15 3
72	3 97	4 78	5 59	6 40	7 21	8 03	8 87	9 67	11 3	13 0	14 7	15 9
75	4 14	4 98	5 82	6 66	7 51	8 36	9 24	10 1	11 8	13 5	15 2	16 4
78	4 30	5 18	6 05	6 93	7 81	8 69	9 60	10 5	12 2	14 0	15 8	17 0
81	4 45	5 38	6 28	7 19	8 10	9 02	9 97	10 9	12 7	14 6	16 4	17 6
84	4 63	5 56	6 51	7 45	8 40	9 35	10 3	11 3	13 2	15 1	17 0	18 2
87	4 79	5 77	6 74	7 72	8 69	9 67	10 7	11 6	13 6	15 6	17 6	18 8
90	4 96	5 97	6 97	7 98	8 99	10 0	11 1	12 0	14 1	16 1	18 2	19 4
93	5 12	6 17	7 20	8 24	9 29	10 3	11 4	12 4	14 5	16 7	18 8	20 0
96	5 28	6 36	7 43	8 51	9 58	10 7	11 8	12 8	15 0	17 2	19 4	20 6
99	5 45	6 56	7 66	8 77	9 88	11 0	12 2	13 2	15 5	17 7	20 0	21 2
102	5 61	6 76	7 89	9 03	10 2	11 3	12 5	13 6	15 9	18 2	20 6	21 8
105	5 78	6 95	8 12	9 29	10 5	11 7	12 9	14 0	16 4	18 8	21 2	22 4
108	5 94	7 17	8 36	9 56	10 8	12 0	13 3	14 4	16 8	19 3	21 8	23 0
111	6 1	7 35	8 59	9 82	11 1	12 3	13 6	14 8	17 3	19 8	22 3	23 5
114	6 27	7 53	8 82	10 1	11 4	12 6	14 0	15 2	17 8	20 3	22 9	24 1
117	6 43	7 74	9 05	10 4	11 7	13 0	14 3	15 6	18 2	20 9	23 5	24 7
120	6 59	7 94	9 28	10 6	12 0	13 3	14 7	16 0	18 7	21 4	24 1	25 3

TABLE 155. -CAST-IRON CYLINDERS - WEIGHT BY EXTERNAL DIAMETER
Length, 1 Foot

External Diameter	Thickness in Inches						
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1 $\frac{1}{8}$	1 $\frac{1}{2}$	2
Inches	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3	9 65	11 0	12 3	14 6	16 6	18 3	19 6
3 $\frac{1}{2}$	11 5	13 2	14 7	17 6	20 3	22 6	24 5
4	13 3	15 3	17 2	20 7	24 0	26 9	29 5
4 $\frac{1}{2}$	15 2	17 5	19 6	23 8	27 7	31 1	34 4
5	17 0	19 6	22 1	26 9	31 5	35 4	39 9
5 $\frac{1}{2}$	18 9	21 8	24 5	29 9	35 2	39 7	44 2
6	20 7	23 9	27 0	33 0	38 9	44 0	49 1
6 $\frac{1}{2}$	22 5	26 0	29 5	35 1	42 6	48 3	54 0

TABLE 156. CAST-IRON CYLINDERS (*continued*)

External Diameter	Thickness in Inches						
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7	24.4	28.2	31.5	39.1	46.4	52.6	58.9
7 $\frac{1}{2}$	26.2	30.3	34.4	42.2	50.1	56.9	63.8
8	28.1	32.5	36.8	45.3	53.8	61.2	68.7
8 $\frac{1}{2}$	29.9	34.6	39.3	48.3	57.5	65.5	73.0
9	31.8	36.8	41.7	51.4	61.3	69.8	78.5
9 $\frac{1}{2}$	33.6	38.9	44.2	54.5	65.0	74.1	83.5
10	35.4	41.1	46.6	57.5	68.7	78.4	88.4
11	39.1	45.4	51.5	63.7	76.0	87.0	98.2
12	42.8	49.7	56.5	69.8	83.4	95.5	108.0
13	46.5	54.0	61.4	75.9	90.7	104.2	117.8
14	50.2	58.3	66.3	82.1	98.0	112.8	127.6
15	53.8	62.6	71.2	88.2	105.4	121.3	137.4
16	57.5	66.9	76.1	94.3	112.7	129.9	147.3
17	61.2	71.1	81.0	100.5	120.0	138.5	157.1
18	64.9	75.4	85.9	106.6	127.4	147.1	166.9
19	68.6	79.7	90.8	112.8	134.7	155.7	176.7
20	72.3	84.0	95.7	118.9	142.0	164.3	186.5
21	75.9	88.3	100.6	125.0	149.4	172.9	196.4
22	79.6	92.6	105.5	131.2	156.7	181.5	206.2
23	83.3	96.9	110.5	137.3	164.0	190.1	215.0
24	87.0	101.2	115.4	143.4	171.4	198.7	225.8
25	90.7	105.5	120.3	149.6	178.7	207.2	235.6
26	94.3	109.8	125.2	155.7	186.1	215.8	245.4
27	98.0	114.1	130.1	161.8	193.4	224.4	255.3
28	101.7	118.4	135.0	168.0	200.7	233.0	265.1
29	105.4	122.7	139.9	174.1	208.1	241.6	274.9
30	109.1	127.0	144.8	180.2	215.4	250.2	284.7
31	112.8	131.3	149.7	186.4	222.7	258.8	294.5
32	116.4	135.6	154.6	192.5	230.1	267.4	304.3
33	120.1	139.9	159.5	198.7	237.5	276.0	314.2
34	123.8	144.2	164.5	204.8	244.8	284.6	324.0
35	127.5	148.5	169.4	210.9	252.2	293.1	333.8
36	131.2	152.7	174.3	217.1	259.5	301.7	343.6
38	138.5	161.3	184.1	229.3	271.3	318.9	363.2
40	145.9	169.9	193.9	241.6	282.0	336.1	382.9
42	153.3	178.5	203.7	253.9	303.7	353.3	402.5
45	164.3	191.2	218.5	272.8	325.8	375.1	437.0
48	175.4	203.8	233.2	290.7	347.9	404.8	461.4
51	186.4	216.5	247.9	303.1	370.0	430.6	490.0
54	197.5	229.2	262.6	327.3	392.1	456.4	520.3
57	208.5	241.8	277.4	345.9	414.2	482.1	549.8
60	219.6	254.5	292.1	364.3	436.3	507.9	579.3

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter	Thickness in Inches.						
	$\frac{1}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
63	2 06	2 39	2 74	3 42	4 09	4 77	5 48
66	2 16	2 50	2 87	3 58	4 29	5 00	5 70
69	2 26	2 62	3 00	3 75	4 49	5 23	5 96
72	2 36	2 74	3 14	3 91	4 69	5 46	6 22
75	2 46	2 85	3 27	4 08	4 88	5 69	6 49
78	2 55	2 97	3 40	4 24	5 08	5 92	6 75
81	2 65	3 09	3 53	4 41	5 28	6 15	7 01
84	2 75	3 20	3 66	4 57	5 47	6 38	7 28
90	2 95	3 43	3 92	4 90	5 87	6 84	7 80
96	3 15	3 67	4 19	5 23	6 26	7 30	8 35

External Diameter	Thickness in Inches.						
	1 $\frac{1}{8}$	1 $\frac{1}{4}$	1 $\frac{3}{8}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	2	2 $\frac{1}{4}$
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
6	481	520	557	592	652	701	740
6 $\frac{1}{2}$	530	575	618	657	729	789	835
7	579	630	678	723	805	876	925
7 $\frac{1}{2}$	629	685	738	789	882	964	1 04
8	678	740	799	855	959	1 05	1 14
8 $\frac{1}{2}$	727	794	859	921	1 04	1 14	1 23
9	777	849	919	986	1 11	1 23	1 33
9 $\frac{1}{2}$	826	904	980	1 06	1 19	1 31	1 43
10	875	959	1 04	1 12	1 27	1 40	1 53
11	974	1 07	1 16	1 25	1 42	1 58	1 75
12	1 07	1 18	1 28	1 38	1 57	1 75	1 92
13	1 17	1 29	1 40	1 51	1 73	1 93	2 13
14	1 27	1 40	1 52	2 04	1 88	2 10	2 32
15	1 37	1 51	1 65	2 78	2 03	2 28	2 52
16	1 47	1 62	1 77	1 91	2 19	2 45	2 71
17	1 57	1 73	1 89	2 04	2 34	2 63	2 91
18	1 66	1 84	2 01	2 17	2 49	2 81	3 11
20	1 86	2 06	2 25	2 43	2 80	3 16	3 50
22	2 06	2 27	2 49	2 70	3 11	3 51	3 90
24	2 26	2 49	2 73	2 96	3 41	3 86	4 29
27	2 55	2 82	3 09	3 35	3 87	4 38	4 88
30	2 85	3 15	3 46	3 75	4 33	4 91	5 47
33	3 14	3 48	3 82	4 14	4 79	5 44	6 06
36	3 44	3 81	4 18	4 54	5 25	5 96	6 66
39	3 74	4 14	4 54	4 93	5 72	6 45	7 23

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter	Thickness in Inches.						
	1 $\frac{1}{8}$	1 $\frac{1}{4}$	1 $\frac{3}{8}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	2	2 $\frac{1}{2}$
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
42	4.03	4.47	4.90	5.33	6.18	7.01	7.84
45	4.33	4.79	5.20	5.72	6.64	7.54	8.43
48	4.62	5.12	5.62	6.12	7.10	8.07	9.02
51	4.92	5.45	5.98	6.51	7.56	8.59	9.61
54	5.22	5.78	6.35	6.91	8.02	9.12	10.2
57	5.51	6.11	6.73	7.30	8.48	9.64	10.8
60	5.81	6.44	7.07	7.70	8.94	10.2	11.4
Ft. In.							
5 3	6.10	6.77	7.43	8.09	9.40	10.7	12.0
5 6	6.40	7.09	7.79	8.48	9.86	11.2	12.6
5 9	6.70	7.42	8.15	8.88	10.3	11.8	13.2
6 0	7.00	7.77	8.53	9.27	10.8	12.3	13.8
6 3	7.29	8.08	8.88	9.67	11.2	12.8	14.4
6 6	7.58	8.41	9.24	10.1	11.7	13.3	14.9
6 9	7.88	8.74	9.60	10.5	12.2	13.9	15.5
7 0	8.17	9.07	9.96	10.9	12.6	14.4	16.1
7 6	8.77	9.72	10.7	11.6	13.5	15.4	17.3
8 0	9.36	10.4	11.4	12.4	14.5	16.5	18.5
8 6	9.95	11.0	12.2	13.2	15.4	17.5	19.7
9 0	10.5	11.7	12.9	14.0	16.3	18.6	20.8
9 6	11.1	12.5	13.6	14.8	17.2	19.6	22.0
10 0	11.7	13.0	14.3	15.6	18.1	20.7	23.2
10 6	12.3	13.7	15.0	16.4	19.1	21.7	24.4
11 0	12.9	14.3	15.7	17.2	20.0	22.8	25.6
11 6	13.5	15.0	16.5	17.9	20.9	23.8	26.7
12 0	14.1	15.6	17.2	18.7	21.8	24.9	27.9
13 0	15.3	16.9	18.6	20.3	23.7	27.0	30.3
14 0	16.5	18.3	20.1	21.9	25.5	29.1	32.7
15 0	17.7	19.6	21.5	23.5	27.3	31.2	35.0
16 0	18.8	20.9	23.0	25	29.2	33.3	37.4
17 0	20.0	22.2	24.4	26.6	31.0	35.4	39.8
18 0	21.2	23.5	25.9	28.2	32.9	37.5	42.2
19 0	22.4	24.8	27.3	29.8	34.7	39.6	44.5
20 0	23.6	26.1	28.8	31.4	36.5	41.7	46.9

TABLE 162.—WEIGHT OF SEAMLESS COPPER TUBES
Calculated on the basis of

		THICKNESS											
B. W. G.		0000	000	00	0	1	2	3	4	5	6	7	
Inches.		0.454	0.420	0.385	0.340	0.300	0.254	0.250	0.238	0.220	0.208	0.188	
Millimetres.		11.53	10.79	9.85	8.64	7.62	6.41	6.35	6.04	5.59	5.16	4.57	
Internal Diameter.		WEIGHT OF A LINEAL											
Inches.	Millim.	3.18	2.83	2.32	1.91	1.54	1.40	1.20	1.04	0.92	0.80	0.64	
1/8	3.2	3.87	3.47	2.90	2.43	2.00	1.83	1.59	1.40	1.26	1.11	0.94	
1/4	6.3	4.55	4.11	3.47	2.94	2.45	2.20	1.90	1.70	1.58	1.42	1.21	
3/8	9.5	5.24	4.78	4.04	3.45	2.90	2.59	2.38	2.12	1.92	1.78	1.49	
1/2	12.7	5.92	5.40	4.62	3.97	3.39	3.12	2.77	2.48	2.26	2.03	1.75	
5/8	15.9	6.61	6.04	5.19	4.48	3.81	3.55	3.16	2.84	2.58	2.34	2.02	
3/4	19.0	7.30	6.68	5.77	5.00	4.26	3.98	3.55	3.20	2.91	2.66	2.30	
7/8	22.2	7.99	7.33	6.34	5.51	4.72	4.41	3.94	3.56	3.25	2.96	2.57	
1	25.4	8.67	7.95	6.92	6.03	5.17	4.84	4.34	3.92	3.58	3.26	2.84	
1 1/8	28.6	9.36	8.61	7.49	6.54	5.62	5.27	4.73	4.28	3.91	3.57	3.11	
1 1/4	31.7	10.04	9.25	8.07	7.06	6.08	5.70	5.12	4.64	4.24	3.87	3.39	
1 1/2	34.9	10.73	9.90	8.64	7.57	6.53	6.13	5.51	5.00	4.58	4.19	3.66	
1 3/4	38.1	11.42	10.54	9.22	8.08	6.99	6.56	5.90	5.36	4.91	4.49	3.93	
2	41.3	12.10	11.18	9.79	8.60	7.44	6.99	6.29	5.72	5.24	4.80	4.20	
2 1/8	44.5	12.79	11.82	10.37	9.11	7.89	7.42	6.68	6.08	5.58	5.10	4.47	
2 1/4	47.7	13.48	12.47	10.94	9.62	8.31	7.85	7.08	6.44	5.91	5.41	4.75	
2 1/2	50.8	14.16	13.11	11.52	10.14	8.80	8.28	7.47	6.80	6.24	5.72	5.03	
2 3/4	54.0	14.85	13.75	12.09	10.65	9.25	8.71	7.86	7.16	6.57	6.02	5.29	
3	57.2	15.54	14.40	12.66	11.17	9.71	9.14	8.25	7.52	6.91	6.33	5.56	
3 1/8	60.4	16.22	15.04	13.24	11.68	10.16	9.56	8.64	7.88	7.24	6.64	5.84	
3 1/4	63.5	16.91	15.68	13.81	12.20	10.62	9.99	9.04	8.24	7.57	6.94	6.11	
3 1/2	66.7	17.60	16.33	14.39	12.71	11.07	10.42	9.43	8.60	7.90	7.25	6.38	
3 3/4	69.8	18.28	16.97	14.96	13.22	11.57	10.85	9.82	8.96	8.24	7.56	6.65	
4	73.0	18.97	17.61	15.54	13.74	11.98	11.25	10.21	9.32	8.57	7.87	6.92	
4 1/8	76.2	19.64	18.20	16.09	14.27	12.48	11.74	10.69	10.04	9.28	8.48	7.47	
4 1/4	79.4	20.32	18.81	16.64	14.79	12.99	12.24	11.18	10.40	9.60	8.79	7.75	
4 1/2	82.5	21.00	19.47	17.18	15.30	13.49	12.74	11.67	10.86	10.03	9.21	8.16	
4 3/4	85.7	21.68	20.13	17.71	15.79	13.99	13.24	12.16	11.33	10.49	9.66	8.59	
5	88.9	22.36	20.79	18.24	16.28	14.48	13.74	12.65	11.80	10.95	10.10	9.02	
5 1/8	92.1	23.04	21.44	18.76	16.76	14.97	14.24	13.14	12.28	11.41	10.55	9.45	
5 1/4	95.3	23.72	22.10	19.28	17.24	15.46	14.74	13.63	12.76	11.88	11.00	9.89	
5 1/2	98.5	24.40	22.75	19.79	17.71	15.94	15.24	14.12	13.24	12.35	11.46	10.34	
5 3/4	101.6	25.08	23.40	20.30	18.18	16.42	15.74	14.61	13.72	12.82	11.91	10.79	
6	104.8	25.76	24.04	20.80	18.64	16.89	16.24	15.10	14.20	13.29	12.37	11.25	
6 1/8	107.9	26.44	24.69	21.29	19.10	17.37	16.74	15.59	14.68	13.76	12.83	11.70	
6 1/4	111.1	27.12	25.34	21.78	19.56	17.84	17.24	16.08	15.16	14.24	13.30	12.16	
6 1/2	114.3	27.80	25.99	22.26	20.01	18.31	17.74	16.57	15.64	14.71	13.76	12.61	
6 3/4	117.5	28.48	26.64	22.74	20.46	18.77	18.24	17.06	16.12	15.18	14.23	13.06	
7	120.6	29.16	27.29	23.22	20.91	19.24	18.74	17.55	16.60	15.65	14.69	13.51	
7 1/8	123.8	29.84	27.94	23.69	21.36	19.70	19.24	18.04	17.08	16.12	15.16	14.00	
7 1/4	127.0	30.52	28.59	24.16	21.81	20.16	19.74	18.53	17.56	16.59	15.62	14.45	
7 1/2	130.2	31.20	29.24	24.63	22.26	20.62	20.24	19.02	18.04	17.06	16.09	14.80	
7 3/4	133.4	31.88	29.89	25.10	22.71	21.08	20.74	19.51	18.52	17.54	16.56	15.10	

Note to Table.—If the External Diameter is given, subtract
The Weight per Lineal Foot of a Copper Tube 2 in. external

TABLE 159.—COPPER AND BRASS. WEIGHT OF ONE SQUARE FOOT

(Elliott's Metal Company.)

On the basis of 558 lb. per cubic foot of Copper and 534 lb. for Brass.

Weight per Square Foot.			Weight per Square Foot.		
Thick- ness.	Copper	Brass.	Thick- ness.	Copper.	Brass.
L. W. G.	Pounds.	Pounds.	L. W. G.	Pounds.	Pounds.
1	13.950	13.350	22	1.302	1.246
2	12.834	12.282	23	1.116	1.068
3	11.718	11.214	24	1.023	.970
4	10.788	10.324	25	.936	.890
5	9.858	9.434	26	.837	.801
6	8.928	8.544	27	.762	.729
7	8.184	7.832	28	.688	.658
8	7.440	7.120	29	.632	.605
9	6.696	6.408	30	.576	.551
10	5.952	5.696	31	.539	.516
11	5.394	5.162	32	.502	.480
12	4.836	4.628	33	.465	.445
13	4.278	4.094	34	.427	.409
14	3.720	3.560	35	.390	.373
15	3.348	3.204	36	.353	.338
16	2.976	2.848	37	.316	.302
17	2.604	2.492	38	.279	.267
18	2.232	2.136	39	.241	.231
19	1.860	1.780	40	.223	.213
20	1.624	1.602	41	.204	.195
21	1.488	1.424	42	.186	.178

TABLE 160.—COPPER APPROXIMATE WEIGHT OF ONE SQUARE FOOT

(Elliott's Metal Company)

Thick- ness.	Approximate Weight per Square Foot.	Thick- ness.	Approximate Weight per Square Foot.	Thick- ness.	Approximate Weight per Square Foot.
L. W. G.		L. W. G.		L. W. G.	
No.	Lbs. Oz.	No.	Lbs. Oz.	No.	Lbs. Oz.
1	14 0	11	5 6	21	1 7½
2	12 14	12	1 13	22	1 5
3	11 12	13	4 4	23	1 2½
4	10 12	14	3 12	24	1 0
5	9 14	15	3 6	25	0 14½
6	9 0	16	3 0	26	0 13½
7	8 2	17	2 10	27	0 12½
8	7 6	18	2 4	28	0 11
9	6 11	19	1 14	29	0 10
10	6 0	20	1 10	30	0 9½

TABLE 162.—WEIGHT OF SEAMLESS COPPER TUBES: BIRMINGHAM
Calculated on the basis of

		THICKNESS										
E. W. G.		0000	000	00	0	1	2	3	4	5	6	7
Inches.		0 464	0 424	0 380	0 340	0 300	0 284	0 250	0 238	0 220	0 203	0 180
Millimetres.		11.53	10.76	9.65	8.64	7.62	7.21	6.35	6.04	5.59	5.16	4.57
Internal Diameter		WEIGHT OF A LINEAL										
Inches.	Millim.											
1	25.4	89.57	30.80	32.78	20.16	25.50	24.17	21.96	20.12	18.55	17.07	15.09
1 1/8	31.75	10.94	38.18	33.98	30.19	26.49	25.08	22.74	20.84	19.22	17.60	15.63
1 1/4	38.1	12.91	53.4	34.08	31.22	27.40	25.88	23.53	21.56	19.88	18.30	16.18
1 3/8	44.45	13.60	10.7	35.12	32.37	28.81	26.74	24.31	22.28	20.55	18.92	16.72
1 1/2	50.8	15.06	12.03	37.8	33.28	29.22	27.00	24.59	22.00	21.21	19.53	17.27
1 5/8	57.15	16.43	43.92	38.52	34.30	30.13	28.46	25.88	23.72	21.88	20.14	17.81
1 3/4	63.5	17.80	44.60	39.67	35.33	31.09	29.32	26.36	24.44	22.54	20.76	18.36
1 7/8	69.85	19.18	45.81	40.82	36.31	31.74	30.18	27.44	25.16	23.17	21.37	18.90
2	76.2	20.55	47.17	41.97	37.39	32.84	31.04	28.28	25.88	23.8	21.99	19.45
2 1/8	82.55	21.92	18.48	43.12	38.42	33.77	31.90	29.01	26.60	24.54	22.60	19.99
2 1/4	88.9	23.30	19.74	44.27	39.47	34.66	32.71	29.76	27.32	25.20	23.21	20.59
2 3/8	95.25	24.67	51.08	45.42	40.4	35.57	33.61	30.58	28.04	25.87	23.83	21.06
2 1/2	101.6	26.04	52.41	46.57	41.50	36.47	34.47	31.37	28.76	26.53	24.44	21.62
2 5/8	107.95	27.40	53.69	47.71	42.53	37.38	35.33	32.14	29.48	27.20	25.06	22.17
3	114.3	28.79	54.89	48.87	43.54	38.29	36.1	32.93	30.20	27.87	25.67	22.71
3 1/8	120.65	30.16	56.17	50.01	44.5	39.19	37.05	33.71	30.37	28.3	26.23	23.26
3 1/4	127	31.51	57.4	51.1	45.9	40.10	37.92	34.49	31.4	29.20	26.90	23.80
3 3/8	133.35	32.84	58.74	52.31	46.94	41.01	38.77	35.35	32.36	29.86	27.51	24.34
3 1/2	139.7	34.18	59.93	53.44	47.94	41.92	39.63	36.06	33.18	30.53	28.13	24.89
3 5/8	146.05	35.51	61.1	54.54	48.97	42.81	40.50	36.84	33.80	31.19	28.74	25.43
3 3/4	152.4	36.85	62.26	55.70	49.93	43.73	41.37	37.6	34.4	31.80	29.35	25.98
3 7/8	158.75	38.18	63.48	56.81	50.91	44.64	42.30	38.41	35.14	32.42	29.97	26.52
4	165.1	39.55	64.67	57.89	51.78	45.57	43.00	39.30	35.85	33.03	30.58	27.07
4 1/8	171.45	40.87	65.84	59.1	52.8	46.46	43.92	40.19	36.68	33.65	31.20	27.61
4 1/4	177.8	42.2	67.1	60.26	53.84	47.39	44.78	41.07	37.40	34.27	31.81	28.16
4 3/8	184.15	43.50	68.31	61.41	54.87	48.31	45.61	41.94	38.11	34.83	32.42	28.70
4 1/2	190.5	44.87	69.51	62.56	55.93	49.18	46.42	42.83	38.83	35.45	33.04	29.24
4 5/8	196.85	46.14	70.63	63.61	56.93	50.08	47.3	43.71	39.75	36.02	33.65	29.79
4 3/4	203.2	47.41	71.84	64.76	57.95	50.98	48.22	44.59	40.77	37.18	34.27	30.33
4 7/8	209.55	48.68	73.04	65.91	58.98	51.90	49.08	45.68	41.90	38.34	34.88	30.88
5	215.9	49.94	74.2	67.06	60.01	52.81	50.01	46.78	43.00	39.45	35.45	31.43

Note to Table.—If the External Diameter is given, subtract per Lineal Foot of a Copper Tube 2 ins. external diameter.

RAM WIRE GAUGE (The Broughton Copper Co.) (continued).
the specific gravity, 8.8917

OF COPPER.

8	9	10	11	12	13	14	15	16	17	18	19	20
0.165	0.148	0.134	0.120	0.106	0.095	0.083	0.072	0.065	0.056	0.049	0.042	0.035
$\frac{1}{16} b$	$\frac{3}{32} f$	$\frac{1}{8} b$	$\frac{1}{16} b$	$\frac{3}{32} f$	$\frac{1}{8} f$	$\frac{3}{32} f$	$\frac{1}{16} b$	$\frac{3}{32} f$	$\frac{1}{8} b$	$\frac{1}{16} b$	$\frac{3}{32} f$	$\frac{1}{8} f$
4.10	3.76	3.40	3.05	2.77	2.41	2.11	1.85	1.65	1.47	1.24	1.07	.89

FOOT IN POUNDS.

13.80	12.85	11.18	9.9	9.04	7.87	6.86	5.94	5.30	4.78	4.03		
14.30	12.80	11.56	10.34	9.37	8.15	7.11	6.6	5.95	4.95	4.18		
14.80	13.25	11.9	10.70	9.70	8.44	7.36	6.48	5.7	4.73			
15.30	13.69	12.37	11.06	10.03	8.73	7.7	6.59	5.96	5.36			
15.80	14.14	12.78	11.52	10.36	9.09	7.86	6.81	6.14	5.48			
16.30	14.59	13.19	11.79	9.99	8.6	8.19	7.03	6.34	5.66			
16.80	15.04	13.59	12.17	11.06	9.69	8.34	7.1	6.41				
17.30	15.48	13.99	12.51	11.3	9.88	8.62	7.47	6.78				
17.79	15.93	14.40	12.88	11.68	10.1	8.87	7.68	6.98				
18.29	16.38	14.81	13.24	12.01	10.45	9.12	7.90	7.18				
18.79	16.83	15.21	13.60	12.34	10.74	9.37	8.12					
19.29	17.27	15.62	13.9	12.64	11.03	9.67	8.34					
19.79	17.72	16.04	14.28	13.06	11.31	9.8	8.55					
20.29	18.17	16.48	14.69	13.33	11.60	10.12	8.77					
20.79	18.62	16.83	15.05	13.7	11.89	10.37						
21.29	19.06	17.24	15.42	13.99	12.18	10.63						
21.79	19.51	17.64	15.78	14.32	12.46	10.88						
22.29	19.96	18.05	16.14	14.65	12.75	11.13						
22.79	20.41	18.45	16.51	14.98	13.04							
23.29	20.86	18.84	16.87	15.31	13.33							
23.79	21.30	19.25	17.25	15.64	13.6							
24.29	21.75	19.67	17.59	15.97	13.8							
24.79	22.19	20.08	17.96	16.30								
25.29	22.63	20.48	18.3	16.63								
25.79	23.09	20.87	18.65	16.96								
26.29	23.53	21.26	19.07	17.29								
26.79	23.99	21.64	19.4									
27.29	24.44	22.01	19.77									
27.79	24.88	22.38	20.13									
28.29	25.32	22.75	20.50									

0.01 0.53 0.43 0.3 0.2 0.1 0.1 0.1 1 0.08 0.04 0.03

Number given at bottom of column, for example. The Weight
2 B. W. G., is 2.78 - 0.29 = 2.49 lbs. *f.* full; *b.* bare.

TABLE 163—WEIGHT OF SEAMLESS BRASS TUBES 70% OF COPPER AND 30% OF ZINC. Specific gravity 8.53. (The Broughton Copper Company). IMPERIAL WIRE GAUGE 1884.

[illegible]

THE GAUGE, 1884 (The Broughton Copper Company).
Specific gravity, 8.8917.

COPPER.

8	9	10	11	12	13	14	15	16	17	18	19	20
0.160	0.144	0.128	0.116	0.104	0.092	0.080	0.068	0.056	0.044	0.032	0.020	0.008
0.64	0.658	0.676	0.694	0.712	0.730	0.748	0.766	0.784	0.802	0.820	0.838	0.856

WT IN POUNDS.

0.65	0.4	0.30	0.34	0.39	0.44	0.50	0.56	0.62	0.68	0.74	0.80	0.87
0.70	0.60	0.58	0.51	0.44	0.38	0.32	0.28	0.24	0.21	0.17	0.14	0.12
1.04	0.90	0.78	0.69	0.60	0.52	0.44	0.36	0.28	0.21	0.15	0.10	0.07
1.28	1.12	0.97	0.86	0.76	0.66	0.56	0.46	0.38	0.32	0.26	0.21	0.17
1.52	1.34	1.17	1.04	0.92	0.80	0.68	0.61	0.53	0.46	0.39	0.32	0.26
1.7	1.56	1.36	1.21	1.07	0.94	0.80	0.72	0.63	0.55	0.47	0.38	0.31
2.00	1.77	1.55	1.36	1.23	1.08	0.92	0.82	0.73	0.63	0.54	0.44	0.36
2.24	1.99	1.75	1.57	1.39	1.21	1.04	0.93	0.82	0.71	0.61	0.50	0.41
2.48	2.21	1.94	1.74	1.55	1.37	1.17	1.04	0.92	0.80	0.68	0.56	0.45
2.72	2.43	2.15	1.92	1.70	1.46	1.29	1.15	1.02	0.88	0.75	0.62	0.50
2.97	2.65	2.35	2.09	1.86	1.63	1.41	1.2	1.11	0.96	0.83	0.68	0.54
3.21	2.86	2.52	2.27	2.02	1.77	1.53	1.3	1.19	1.03	0.89	0.74	0.59
3.45	3.08	2.71	2.44	2.17	1.91	1.65	1.48	1.31	1.14	0.97	0.81	0.65
3.70	3.30	2.91	2.62	2.33	2.05	1.77	1.59	1.41	1.22	1.04	0.87	0.70
3.94	3.52	3.10	2.79	2.49	2.19	1.89	1.70	1.50	1.31	1.12	0.93	0.75
4.18	3.73	3.29	2.97	2.65	2.33	2.01	1.80	1.59	1.38	1.17	0.96	0.77
4.42	3.95	3.49	3.16	2.83	2.50	2.17	1.93	1.71	1.49	1.27	1.05	0.84
4.66	4.16	3.68	3.34	2.99	2.64	2.29	2.03	1.77	1.54	1.31	1.08	0.86
4.91	4.39	3.88	3.53	3.17	2.81	2.44	2.17	1.89	1.65	1.41	1.17	0.94
5.15	4.61	4.07	3.71	3.34	2.97	2.59	2.31	2.01	1.76	1.49	1.24	0.99
5.39	4.82	4.26	3.89	3.51	3.13	2.74	2.45	2.14	1.88	1.61	1.34	1.07
5.63	5.04	4.46	4.08	3.69	3.30	2.90	2.60	2.28	2.00	1.72	1.44	1.15
5.87	5.26	4.66	4.27	3.87	3.47	3.06	2.75	2.42	2.13	1.84	1.55	1.25
6.11	5.48	4.87	4.47	4.06	3.65	3.24	2.92	2.59	2.28	1.97	1.67	1.36
6.35	5.69	5.07	4.66	4.25	3.83	3.41	3.08	2.74	2.42	2.10	1.78	1.45
6.59	5.91	5.28	4.86	4.44	4.01	3.58	3.24	2.89	2.56	2.23	1.90	1.56
6.83	6.12	5.49	5.06	4.63	4.20	3.76	3.41	3.06	2.72	2.38	2.04	1.69
7.07	6.34	5.70	5.26	4.82	4.38	3.93	3.57	3.21	2.85	2.49	2.14	1.78
7.31	6.55	5.90	5.45	5.00	4.55	4.09	3.72	3.35	2.98	2.61	2.24	1.87
7.55	6.77	6.10	5.64	5.18	4.71	4.24	3.86	3.48	3.10	2.72	2.34	1.95
7.79	6.98	6.30	5.83	5.36	4.88	4.40	4.01	3.62	3.23	2.84	2.45	2.05
8.03	7.19	6.50	6.02	5.54	5.05	4.56	4.16	3.76	3.36	2.96	2.56	2.15
8.27	7.40	6.70	6.21	5.72	5.22	4.72	4.31	3.90	3.49	3.08	2.67	2.25
8.51	7.61	6.90	6.40	5.90	5.39	4.88	4.46	4.04	3.62	3.20	2.78	2.35
8.75	7.82	7.10	6.59	6.08	5.56	5.04	4.61	4.18	3.75	3.32	2.89	2.45
8.99	8.03	7.30	6.78	6.26	5.73	5.20	4.76	4.32	3.88	3.44	3.00	2.55
9.23	8.24	7.50	6.97	6.44	5.90	5.36	4.91	4.46	4.01	3.56	3.11	2.65
9.47	8.45	7.70	7.16	6.62	6.07	5.52	5.06	4.60	4.14	3.68	3.22	2.77
9.71	8.66	7.90	7.35	6.80	6.24	5.68	5.21	4.74	4.27	3.80	3.33	2.89
9.95	8.87	8.10	7.54	6.97	6.40	5.83	5.35	4.87	4.39	3.91	3.43	2.95
10.19	9.08	8.30	7.73	7.15	6.57	6.00	5.51	5.02	4.53	4.04	3.55	3.05
10.43	9.29	8.50	7.92	7.33	6.74	6.15	5.65	5.15	4.65	4.15	3.65	3.15
10.67	9.50	8.70	8.11	7.51	6.91	6.31	5.80	5.29	4.78	4.27	3.76	3.25
10.91	9.71	8.90	8.30	7.69	7.08	6.47	5.95	5.43	4.91	4.39	3.87	3.35
11.15	9.92	9.10	8.49	7.87	7.25	6.63	6.10	5.57	5.04	4.51	3.98	3.45
11.39	10.13	9.30	8.68	8.06	7.43	6.80	6.26	5.72	5.18	4.64	4.10	3.55
11.63	10.34	9.50	8.87	8.24	7.60	6.96	6.41	5.86	5.31	4.76	4.21	3.65
11.87	10.55	9.70	9.06	8.42	7.77	7.12	6.56	6.00	5.44	4.88	4.32	3.75
12.11	10.76	9.90	9.25	8.60	7.94	7.28	6.71	6.14	5.57	5.00	4.43	3.85

bottom of column
I. W. G., is 24"

304, 305. For example.—The
39 lbs. f, full; b, bare.

TABLE 161.—WEIGHT OF SEAMLESS COPPER TUBES
(calculated on the basis of 100% copper)

1884.		Tons															
L. W. G.		1000	800	600	400	200	100	50	25	12	6	3	1	1/2	3/4	5/8	3/16
Inches.		1.400	0.870	0.548	0.334	0.200	0.127	0.076	0.043	0.023	0.012	0.006	0.003	0.001	0.001	0.001	0.001
Millimetres.		35.5	22.1	13.9	8.5	5.1	3.2	1.9	1.1	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0
Internal Diameter.		WEIGHT OF A FOOT															
Inches. Millim.																	
1/8	3.2	0.34	0.24	0.16	0.10	0.06	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/4	6.3	0.44	0.30	0.20	0.12	0.07	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/8	9.5	0.77	0.50	0.33	0.20	0.12	0.07	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/2	12.7	0.85	0.55	0.36	0.22	0.13	0.08	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/8	15.9	0.90	0.57	0.38	0.23	0.14	0.09	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/4	19.0	1.00	0.63	0.42	0.26	0.15	0.10	0.06	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7/8	22.2	1.10	0.70	0.46	0.28	0.17	0.11	0.07	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1	25.4	1.20	0.77	0.51	0.31	0.18	0.12	0.07	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1 1/8	28.6	1.30	0.84	0.55	0.34	0.20	0.13	0.08	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1 1/4	31.7	1.40	0.90	0.60	0.37	0.22	0.14	0.09	0.06	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00
1 3/8	34.9	1.50	0.97	0.64	0.40	0.24	0.15	0.10	0.07	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00
1 1/2	38.1	1.60	1.04	0.69	0.43	0.26	0.16	0.11	0.07	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00
1 5/8	41.3	1.70	1.11	0.74	0.46	0.28	0.17	0.12	0.08	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00
1 3/4	44.4	1.80	1.18	0.79	0.49	0.30	0.18	0.13	0.09	0.06	0.04	0.02	0.01	0.00	0.00	0.00	0.00
2	50.8	2.00	1.30	0.87	0.53	0.33	0.20	0.14	0.10	0.07	0.04	0.02	0.01	0.00	0.00	0.00	0.00
2 1/8	54.0	2.10	1.37	0.92	0.56	0.35	0.21	0.15	0.11	0.08	0.05	0.03	0.01	0.00	0.00	0.00	0.00
2 1/4	57.1	2.20	1.44	0.97	0.59	0.37	0.22	0.16	0.12	0.09	0.06	0.04	0.02	0.01	0.00	0.00	0.00
2 3/8	60.3	2.30	1.51	1.02	0.62	0.39	0.23	0.17	0.13	0.10	0.07	0.05	0.03	0.01	0.00	0.00	0.00
2 1/2	63.5	2.40	1.58	1.07	0.65	0.41	0.24	0.18	0.14	0.11	0.08	0.06	0.04	0.02	0.01	0.00	0.00
2 5/8	66.7	2.50	1.65	1.12	0.68	0.43	0.25	0.19	0.15	0.12	0.09	0.07	0.05	0.03	0.01	0.00	0.00
3	72.9	2.70	1.77	1.22	0.74	0.47	0.28	0.21	0.17	0.14	0.11	0.08	0.06	0.04	0.02	0.01	0.00
3 1/8	76.2	2.80	1.84	1.27	0.77	0.49	0.30	0.22	0.18	0.15	0.12	0.09	0.07	0.05	0.03	0.01	0.00
3 1/4	79.4	2.90	1.91	1.32	0.80	0.51	0.31	0.23	0.19	0.16	0.13	0.10	0.08	0.06	0.04	0.02	0.01
3 3/8	82.6	3.00	1.98	1.37	0.83	0.53	0.32	0.24	0.20	0.17	0.14	0.11	0.09	0.07	0.05	0.03	0.01
3 1/2	85.8	3.10	2.05	1.42	0.86	0.55	0.33	0.25	0.21	0.18	0.15	0.12	0.10	0.08	0.06	0.04	0.02
4	101.6	3.40	2.20	1.55	0.94	0.60	0.36	0.28	0.23	0.20	0.17	0.14	0.11	0.09	0.07	0.05	0.03
4 1/8	104.8	3.50	2.27	1.60	0.97	0.62	0.37	0.29	0.24	0.21	0.18	0.15	0.12	0.10	0.08	0.06	0.04
4 1/4	107.9	3.60	2.34	1.65	1.00	0.64	0.38	0.30	0.25	0.22	0.19	0.16	0.13	0.11	0.09	0.07	0.05
4 3/8	111.1	3.70	2.41	1.70	1.03	0.66	0.39	0.31	0.26	0.23	0.20	0.17	0.14	0.12	0.10	0.08	0.06
4 1/2	114.3	3.80	2.48	1.75	1.06	0.68	0.40	0.32	0.27	0.24	0.21	0.18	0.15	0.13	0.11	0.09	0.07
5	127.0	4.10	2.65	1.88	1.14	0.74	0.44	0.35	0.30	0.27	0.24	0.21	0.18	0.15	0.13	0.11	0.09
5 1/8	130.2	4.20	2.72	1.93	1.17	0.76	0.45	0.36	0.31	0.28	0.25	0.22	0.19	0.16	0.14	0.12	0.10
5 1/4	133.4	4.30	2.79	1.98	1.20	0.78	0.46	0.37	0.32	0.29	0.26	0.23	0.20	0.17	0.15	0.13	0.11
5 3/8	136.6	4.40	2.86	2.03	1.23	0.80	0.47	0.38	0.33	0.30	0.27	0.24	0.21	0.18	0.16	0.14	0.12
5 1/2	139.8	4.50	2.93	2.08	1.26	0.82	0.48	0.39	0.34	0.31	0.28	0.25	0.22	0.19	0.17	0.15	0.13
6	152.4	4.80	3.10	2.22	1.34	0.88	0.52	0.43	0.37	0.34	0.31	0.28	0.25	0.22	0.20	0.18	0.16
6 1/8	155.6	4.90	3.17	2.27	1.37	0.90	0.53	0.44	0.38	0.35	0.32	0.29	0.26	0.23	0.21	0.19	0.17
6 1/4	158.8	5.00	3.24	2.32	1.40	0.92	0.54	0.45	0.39	0.36	0.33	0.30	0.27	0.24	0.22	0.20	0.18
6 3/8	162.0	5.10	3.31	2.37	1.43	0.94	0.55	0.46	0.40	0.37	0.34	0.31	0.28	0.25	0.23	0.21	0.19
6 1/2	165.1	5.20	3.38	2.42	1.46	0.96	0.56	0.47	0.41	0.38	0.35	0.32	0.29	0.26	0.24	0.22	0.20

Note to Table.—If the External Diameter is given, subtract the weight of the internal diameter from the weight of the external diameter to get the weight of the tube.

GAUGE, 1884 (The Broughton Copper Company).

Specific gravity, 8.917.

COPPER.

	9	10	11	12	13	14	15	16	17	18	19	20
100	144	0.128	0.116	0.104	0.092	0.080	0.068	0.056	0.044	0.032	0.020	0.008
$\frac{1}{16}$ f	$\frac{1}{16}$ b	$\frac{1}{16}$ f	$\frac{1}{16}$ b	$\frac{1}{16}$ f	$\frac{1}{16}$ b	$\frac{1}{16}$ f	$\frac{1}{16}$ b	$\frac{1}{16}$ f	$\frac{1}{16}$ b	$\frac{1}{16}$ f	$\frac{1}{16}$ b	$\frac{1}{16}$ f
100	6.8	3.251	2.946	2.642	2.337	2.032	1.727	1.422	1.117	0.812	0.507	0.202

IN POUNDS.

90	0.4	0.39	0.34	0.29	0.24	0.20	0.17	0.14	0.12	0.10	0.08	0.07
91	0.49	0.38	0.31	0.24	0.18	0.12	0.08	0.05	0.03	0.02	0.01	0.00
92	0.99	0.78	0.60	0.40	0.32	0.24	0.19	0.14	0.10	0.07	0.05	0.04
93	1.12	0.97	0.88	0.76	0.66	0.56	0.46	0.38	0.32	0.26	0.20	0.18
94	1.34	1.17	1.04	0.92	0.80	0.68	0.58	0.46	0.36	0.26	0.16	0.10
95	1.56	1.36	1.21	1.07	0.94	0.80	0.72	0.61	0.55	0.44	0.38	0.30
96	1.77	1.55	1.39	1.23	1.08	0.92	0.82	0.73	0.63	0.54	0.44	0.36
97	1.99	1.75	1.57	1.39	1.21	1.04	0.93	0.82	0.71	0.6	0.50	0.41
98	2.21	1.94	1.74	1.55	1.35	1.17	1.04	0.91	0.80	0.68	0.56	0.51
99	2.43	2.13	1.92	1.70	1.44	1.29	1.15	1.02	0.88	0.77	0.62	0.56
100	2.65	2.33	2.09	1.86	1.63	1.41	1.26	1.11	0.97	0.83	0.68	0.61
101	2.87	2.52	2.27	2.02	1.77	1.53	1.37	1.21	1.05	0.90	0.74	0.67
102	3.08	2.71	2.44	2.17	1.90	1.63	1.48	1.31	1.14	0.97	0.81	0.72
103	3.30	2.91	2.62	2.33	2.07	1.77	1.60	1.40	1.22	1.04	0.87	0.78
104	3.52	3.10	2.79	2.49	2.18	1.85	1.67	1.46	1.27	1.08	0.90	0.81
105	3.74	3.30	2.97	2.65	2.33	2.00	1.80	1.60	1.40	1.19	0.98	0.89
106	3.96	3.49	3.14	2.80	2.45	2.10	1.87	1.66	1.45	1.24	1.03	0.94
107	4.17	3.68	3.32	2.96	2.59	2.22	1.97	1.75	1.54	1.33	1.11	1.00
108	4.39	3.88	3.50	3.12	2.75	2.38	2.11	1.88	1.66	1.44	1.22	1.10
109	4.61	4.07	3.67	3.28	2.88	2.48	2.20	1.96	1.73	1.50	1.28	1.16
110	4.82	4.26	3.85	3.43	3.02	2.62	2.33	2.08	1.84	1.60	1.37	1.24
111	5.04	4.46	4.04	3.61	3.19	2.77	2.46	2.19	1.94	1.69	1.45	1.31
112	5.26	4.65	4.23	3.79	3.36	2.93	2.61	2.33	2.07	1.81	1.56	1.41
113	5.48	4.84	4.41	3.96	3.53	3.10	2.77	2.48	2.21	1.94	1.68	1.52
114	5.69	5.04	4.60	4.15	3.71	3.27	2.93	2.63	2.35	2.07	1.80	1.64
115	5.91	5.24	4.79	4.33	3.88	3.43	3.08	2.77	2.47	2.18	1.89	1.73
116	6.13	5.44	4.98	4.51	4.05	3.59	3.23	2.91	2.60	2.30	2.00	1.84
117	6.35	5.64	5.17	4.70	4.23	3.76	3.39	3.06	2.74	2.43	2.12	1.95
118	6.57	5.84	5.36	4.88	4.40	3.92	3.54	3.20	2.87	2.55	2.23	2.06
119	6.79	6.04	5.55	5.06	4.57	4.08	3.69	3.34	3.00	2.67	2.34	2.17
120	7.01	6.24	5.74	5.24	4.74	4.24	3.84	3.48	3.13	2.79	2.45	2.28
121	7.23	6.44	5.93	5.42	4.91	4.40	3.99	3.62	3.26	2.91	2.56	2.39
122	7.45	6.64	6.12	5.60	5.08	4.56	4.14	3.76	3.39	3.03	2.67	2.50
123	7.67	6.84	6.31	5.78	5.25	4.72	4.29	3.90	3.52	3.15	2.78	2.61
124	7.89	7.04	6.50	5.96	5.42	4.88	4.44	4.04	3.65	3.27	2.89	2.72
125	8.11	7.24	6.69	6.14	5.59	5.04	4.59	4.18	3.78	3.39	3.00	2.83
126	8.33	7.44	6.88	6.32	5.76	5.20	4.74	4.32	3.91	3.51	3.11	2.94
127	8.55	7.64	7.07	6.50	5.93	5.36	4.89	4.46	4.04	3.63	3.22	3.05
128	8.77	7.84	7.26	6.68	6.10	5.52	5.04	4.61	4.18	3.76	3.35	3.18
129	8.99	8.04	7.45	6.86	6.27	5.68	5.19	4.75	4.32	3.89	3.47	3.30
130	9.21	8.24	7.64	7.04	6.44	5.84	5.34	4.89	4.46	4.03	3.60	3.43
131	9.43	8.44	7.83	7.22	6.61	6.00	5.49	5.03	4.59	4.15	3.72	3.55
132	9.65	8.64	8.02	7.40	6.78	6.16	5.64	5.17	4.66	4.19	3.74	3.57
133	9.87	8.84	8.21	7.58	6.95	6.32	5.79	5.26	4.72	4.28	3.84	3.67
134	10.09	9.04	8.40	7.76	7.12	6.48	5.94	5.45	4.90	4.44	4.00	3.79
135	10.31	9.24	8.59	7.94	7.29	6.64	6.09	5.59	5.13	4.67	4.21	3.92
136	10.53	9.44	8.78	8.12	7.46	6.80	6.24	5.73	5.26	4.79	4.32	4.04
137	10.75	9.64	8.97	8.30	7.63	6.96	6.39	5.87	5.39	4.91	4.44	4.15
138	10.97	9.84	9.16	8.48	7.80	7.12	6.54	6.01	5.52	5.03	4.55	4.27
139	11.19	10.04	9.35	8.66	7.97	7.28	6.69	6.15	5.65	5.15	4.66	4.38
140	11.41	10.24	9.54	8.84	8.14	7.44	6.84	6.29	5.78	5.27	4.77	4.49
141	11.63	10.44	9.73	9.02	8.31	7.60	6.99	6.43	5.91	5.39	4.88	4.60
142	11.85	10.64	9.92	9.20	8.48	7.76	7.14	6.57	6.04	5.51	5.00	4.71
143	12.07	10.84	10.11	9.38	8.65	7.92	7.29	6.71	6.17	5.63	5.09	4.83
144	12.29	11.04	10.30	9.56	8.82	8.08	7.44	6.85	6.30	5.75	5.20	4.94
145	12.51	11.24	10.49	9.74	8.99	8.24	7.59	6.99	6.43	5.87	5.32	5.06
146	12.73	11.44	10.68	9.92	9.16	8.40	7.74	7.13	6.56	6.00	5.45	5.18
147	12.95	11.64	10.87	10.10	9.33	8.56	7.89	7.27	6.69	6.12	5.57	5.30
148	13.17	11.84	11.06	10.28	9.50	8.72	8.04	7.41	6.82	6.25	5.69	5.42
149	13.39	12.04	11.25	10.46	9.67	8.88	8.19	7.55	6.95	6.37	5.80	5.54
150	13.61	12.24	11.44	10.64	9.84	9.04	8.34	7.69	7.08	6.49	5.91	5.66
151	13.83	12.44	11.63	10.82	10.01	9.20	8.49	7.83	7.21	6.61	6.02	5.77
152	14.05	12.64	11.82	11.00	10.18	9.36	8.64	7.97	7.35	6.74	6.14	5.89
153	14.27	12.84	12.00	11.18	10.35	9.52	8.79	8.11	7.48	6.86	6.25	6.01
154	14.49	13.04	12.19	11.36	10.52	9.68	8.94	8.25	7.61	6.99	6.37	6.13
155	14.71	13.24	12.37	11.54	10.69	9.84	9.09	8.39	7.74	7.11	6.49	6.29
156	14.93	13.44	12.56	11.72	10.86	10.00	9.24	8.53	7.87	7.24	6.61	6.45
157	15.15	13.64	12.74	11.90	11.03	10.16	9.39	8.67	8.00	7.36	6.73	6.61
158	15.37	13.84	12.92	12.08	11.20	10.32	9.54	8.81	8.13	7.48	6.84	6.77
159	15.59	14.04	13.10	12.26	11.37	10.48	9.70	8.96	8.27	7.61	6.97	6.93
160	15.81	14.24	13.27	12.44	11.54	10.64	9.86	9.11	8.41	7.74	7.10	7.09
161	16.03	14.44	13.45	12.62	11.71	10.80	10.02	9.26	8.55	7.87	7.23	7.25
162	16.25	14.64	13.62	12.80	11.88	10.96	10.18	9.41	8.69	8.00	7.35	7.47
163	16.47	14.84	13.80	12.98	12.05	11.12	10.34	9.56	8.83	8.13	7.47	7.69
164	16.69	15.04	13.97	13.16	12.22	11.28	10.50	9.71	8.97	8.26	7.59	7.91
165	16.91	15.24	14.15	13.34	12.39	11.44	10.66	9.87	9.12	8.40	7.74	8.13
166	17.13	15.44	14.32	13.52	12.56	11.60	10.82	10.03	9.27	8.55	7.90	8.35
167	17.35	15.64	14.50	13.70	12.73	11.76	10.98	10.19	9.42	8.69	8.04	8.57
168	17.57	15.84	14.67	13.88	12.90	11.92	11.14	10.35	9.58	8.85	8.20	8.79
169	17.79	16.04	14.85	14.06	13.07	12.08	11.30	10.51	9.74	9.01	8.36	9.01
170	18.01	16.24	15.02	14.24	13.24	12.24	11.46	10.67	9.89	9.17	8.52	9.23
171	18.23	16.44	15.20	14.42	13.41	12.40	11.62	10.83	10.05	9.32	8.67	9.45
172	18.45	16.64	15.37	14.60	13.58	12.56	11.78	10.99	10.21	9.47	8.83	9.67
173	18.67	16.84	15.55	14.78	13.75	12.72	11.94	11.15	10.37	9.63	9.00	9.89
174	18.89	17.04	15.72	14.96	13.92	12.88	12.10	11.31	10.53	9.79	9.16	10.11
175	19.11	17.24	15.90	15.14	14.09	13.04	12.26	11.47	10.69	9.95	9.32	10.33
176	19.33	17.44	16.07	15.32	14.26	13.20	12.42	11.63	10.85	10.11	9.48	10.55
177	19.55	17.64	16.25	15.50	14.43	13.36	12.58	11.79	11.01	10.27	9.64	10.77
178	19.77	17.84	16.42	15.68	14.60	13.52	12.74	11.95	11.17	10.43	9.80	10.99
179	19.99	18.04	16.60	15.86	14.77	13.68	12.90	12.11	11.33	10.59	9.96	11.21
180	20.21	18.24	16.77	16.04	14.94	13.84	13.06	12.27	11.49	10.75	10.12	11.43
181	20.43	18.44	16.95	16.22	15.11	14.00	13.22	12.43	11.65	10.91	10.28	11.65
182	20.65	18.64	17.12	16.40	15.28	14.16	13.38	12.59	11.81	11.07	10.44	11.87
183	20.87	18.84	17.30	16.58	15.45	14.32	13.54	12.75	11.97	11.23	10.60	12.09
184	21.09	19.04	17.47	16.76	15.62	14.48	13.70	12.91	12.13	11.39	10.76	12.31
185	21.31	19.24	17.65	16.94	15.79	14.64	13.86	13.07	12.29	11.55	10.92	12.53
186	21.53	19.44	17.82	17.12	15.96	14.80	14.02	13.23	12.45	11.71	11.08	12.75
187	21.75	19.64	18.00	17.30	16.13	14.96	14.18	13.39	12.61	11.87	11.24	12.97
188	21.97											

TABLE 162. WEIGHT OF SEAMLESS COPPER TUBE.
(Calculated on the basis of 8.9 lb. per cu. in.)

		THICKNESS										
B. W. G.		0000	000	00	0	1	2	3	4	5	6	7
Inches.		0.451	0.421	0.380	0.340	0.300	0.284	0.259	0.238	0.220	0.203	0.187
Millimetres.		11.53	10.71	9.65	8.64	7.62	7.31	6.58	6.04	5.59	5.16	4.75
Internal Diameter		WEIGHT OF A LINEAL FOOT										
Inches.	Millim.											
1/8	3.2	3.18	2.83	2.82	1.91	1.54	1.40	1.20	1.04	0.80	0.80	0.80
1/8	6.3	3.87	3.47	2.90	2.43	2.00	1.85	1.59	1.40	1.25	1.11	0.98
1/8	9.5	4.57	4.11	3.47	2.94	2.47	2.26	1.90	1.76	1.58	1.42	1.27
1/8	12.7	5.24	4.78	4.04	3.45	2.90	2.60	2.38	2.12	1.92	1.73	1.56
1/8	15.9	5.92	5.40	4.62	3.97	3.36	3.02	2.77	2.48	2.25	2.03	1.84
1/8	19.0	6.61	6.04	5.10	4.48	3.81	3.45	3.16	2.84	2.58	2.34	2.14
1/8	22.2	7.30	6.68	5.57	5.00	4.28	3.88	3.55	3.20	2.91	2.65	2.41
1/8	25.4	7.99	7.33	6.34	5.51	4.72	4.31	3.94	3.56	3.25	2.95	2.69
1/8	28.6	8.67	7.95	6.92	6.03	5.17	4.84	4.34	3.92	3.58	3.26	2.97
1/8	31.7	9.36	8.61	7.49	6.54	5.62	5.27	4.73	4.28	3.91	3.57	3.25
1/8	34.9	10.04	9.25	8.07	7.05	6.08	5.70	5.12	4.64	4.24	3.87	3.52
1/8	38.1	10.73	9.90	8.64	7.57	6.53	6.13	5.51	5.00	4.58	4.18	3.79
1/8	41.3	11.42	10.54	9.22	8.08	6.99	6.56	5.90	5.39	4.91	4.49	4.07
1/8	44.4	12.10	11.18	9.79	8.60	7.44	6.99	6.29	5.72	5.24	4.80	4.35
1/8	47.6	12.79	11.82	10.37	9.11	7.89	7.42	6.68	6.08	5.58	5.10	4.63
1/8	50.8	13.48	12.46	10.94	9.62	8.35	7.87	7.08	6.44	5.91	5.41	4.92
1/8	54.0	14.16	13.11	11.52	10.14	8.80	8.28	7.47	6.80	6.24	5.71	5.21
1/8	57.1	14.85	13.77	12.09	10.65	9.25	8.71	7.86	7.16	6.57	6.02	5.50
1/8	60.3	15.54	14.42	12.69	11.17	9.71	9.14	8.25	7.52	6.91	6.33	5.79
1/8	63.5	16.23	15.07	13.24	11.68	10.16	9.56	8.64	7.88	7.24	6.64	6.09
1/8	66.7	16.92	15.72	13.81	12.20	10.61	10.00	9.04	8.24	7.57	6.94	6.38
1/8	69.9	17.61	16.42	14.39	12.71	11.07	10.42	9.43	8.60	7.90	7.25	6.67
1/8	73.0	18.30	17.07	14.98	13.24	11.52	10.85	9.82	8.96	8.24	7.56	6.96
1/8	76.2	18.99	17.72	15.54	13.74	12.08	11.28	10.21	9.32	8.57	7.87	7.25
1/8	79.4	19.68	18.37	16.10	14.27	12.58	12.14	10.91	9.94	9.23	8.48	7.84
1/8	82.6	20.37	19.00	16.64	14.77	13.08	12.44	11.00	10.04	9.28	8.48	7.84
1/8	85.8	21.06	19.64	17.18	15.24	13.57	12.88	11.40	10.42	9.64	8.81	8.17
1/8	89.0	21.75	20.27	17.72	15.71	14.07	13.37	11.85	10.85	10.04	9.19	8.53
1/8	92.2	22.44	20.90	18.26	16.18	14.56	13.85	12.30	11.28	10.45	9.58	8.90
1/8	95.4	23.13	21.53	18.80	16.64	15.05	14.34	12.75	11.72	10.87	10.00	9.30
1/8	98.6	23.82	22.16	19.34	17.11	15.54	14.82	13.20	12.16	11.30	10.41	9.69
1/8	101.8	24.51	22.79	19.88	17.58	16.03	15.30	13.65	12.60	11.72	10.81	10.09
1/8	105.0	25.20	23.42	20.42	18.05	16.52	15.77	14.10	13.04	12.15	11.22	10.36
1/8	108.2	25.89	24.05	20.96	18.52	17.01	16.24	14.55	13.47	12.57	11.64	10.63
1/8	111.4	26.58	24.68	21.50	19.00	17.50	16.72	15.00	13.90	13.00	12.06	10.90
1/8	114.6	27.27	25.31	22.04	19.47	17.99	17.21	15.45	14.34	13.43	12.48	11.17
1/8	117.8	27.96	25.94	22.58	19.94	18.48	17.69	15.90	14.78	13.86	12.90	11.44
1/8	121.0	28.65	26.57	23.12	20.41	18.97	18.18	16.40	15.27	14.34	13.37	11.71
1/8	124.2	29.34	27.20	23.66	20.88	19.46	18.67	16.91	15.77	14.83	13.85	12.00
1/8	127.4	30.03	27.83	24.20	21.35	20.00	19.18	17.40	16.25	15.30	14.31	12.27
1/8	130.6	30.72	28.46	24.74	21.82	20.53	19.69	17.91	16.75	15.79	14.79	12.54
1/8	133.8	31.41	29.09	25.28	22.29	21.07	20.21	18.42	17.25	16.28	15.27	12.81
1/8	137.0	32.10	29.72	25.82	22.76	21.60	20.74	18.93	17.76	16.78	15.76	13.08
1/8	140.2	32.79	30.35	26.36	23.23	22.13	21.27	19.44	18.27	17.28	16.03	13.35
1/8	143.4	33.48	30.98	26.90	23.70	22.67	21.80	19.96	18.79	17.79	16.53	13.62
1/8	146.6	34.17	31.61	27.44	24.17	23.20	22.33	20.47	19.30	18.29	17.01	13.89
1/8	149.8	34.86	32.24	27.98	24.64	23.74	22.86	20.98	19.80	18.79	17.28	14.16
1/8	153.0	35.55	32.87	28.52	25.11	24.27	23.39	21.49	20.30	19.28	17.55	14.43
1/8	156.2	36.24	33.50	29.06	25.58	24.81	23.92	22.00	20.81	19.78	17.82	14.70
1/8	159.4	36.93	34.13	29.60	26.05	25.34	24.45	22.51	21.32	20.28	18.09	14.97
1/8	162.6	37.62	34.76	30.14	26.52	25.87	24.98	23.02	21.83	20.78	18.36	15.24
1/8	165.8	38.31	35.39	30.68	26.99	26.41	25.51	23.53	22.34	21.29	18.63	15.51

Note to Table.—If the External Diameter is given, subtract the Weight per Lineal Foot of a Copper Tube 2 ins. ext.

COPPER TUBES.

39

BIRMINGHAM WIRE GAUGE (The Broughton Copper Co.),
the specific gravity, 8.8917.

OF COPPER.

9	10	11	12	13	14	15	16	17	18	19	20	
0.165	0.146	0.134	0.120	0.109	0.099	0.088	0.077	0.065	0.058	0.049	0.042	0.036
$\frac{11}{16}$ b	$\frac{7}{8}$ f	$\frac{5}{8}$ b	$\frac{1}{2}$ b	$\frac{3}{4}$ f	$\frac{1}{2}$ f	$\frac{3}{8}$ f	$\frac{1}{4}$ b	$\frac{1}{8}$ f	$\frac{1}{16}$ b	$\frac{1}{32}$ f	$\frac{1}{64}$ b	$\frac{1}{128}$ f
4.19	3.71	3.40	3.05	2.77	2.41	2.11	1.88	1.65	1.47	1.24	1.07	0.89

FOOT IN POUNDS.

0.58	0.49	0.42	0.36	0.31	0.25	0.21	0.17	0.14	0.13	0.10	0.08	0.07
0.83	0.71	0.62	0.54	0.47	0.40	0.33	0.27	0.23	0.20	0.18	0.15	0.12
1.08	0.94	0.82	0.72	0.64	0.54	0.46	0.39	0.35	0.30	0.25	0.21	0.17
1.33	1.16	1.03	0.90	0.80	0.68	0.58	0.50	0.44	0.39	0.32	0.27	0.23
1.58	1.38	1.23	1.08	0.97	0.83	0.71	0.61	0.54	0.48	0.40	0.34	0.28
1.83	1.61	1.43	1.26	1.13	0.97	0.84	0.72	0.64	0.56	0.47	0.40	0.33
2.08	1.83	1.64	1.44	1.30	1.11	0.96	0.82	0.74	0.65	0.55	0.47	0.39
2.32	2.07	1.84	1.63	1.48	1.29	1.09	0.93	0.84	0.74	0.63	0.53	0.44
2.57	2.28	2.04	1.81	1.63	1.40	1.21	1.04	0.94	0.83	0.70	0.60	0.49
2.82	2.49	2.24	1.99	1.79	1.57	1.34	1.15	1.03	0.92	0.77	0.66	0.54
3.07	2.73	2.45	2.17	1.96	1.73	1.49	1.30	1.17	1.05	0.88	0.76	0.63
3.32	2.97	2.66	2.35	2.12	1.87	1.59	1.37	1.23	1.09	0.92	0.78	0.65
3.57	3.21	2.86	2.52	2.27	1.98	1.71	1.48	1.33	1.18	0.99	0.85	0.70
3.82	3.45	3.05	2.69	2.41	2.12	1.84	1.59	1.43	1.27	1.07	0.94	0.78
4.07	3.62	3.26	2.86	2.40	2.02	1.70	1.40	1.27	1.14	0.97	0.81	0.66
4.32	3.85	3.46	3.08	2.78	2.41	2.00	1.80	1.62	1.44	1.21	1.04	0.86
4.57	4.07	3.66	3.26	2.93	2.53	2.22	1.91	1.72	1.53	1.29	1.10	0.91
4.82	4.29	3.86	3.44	3.11	2.69	2.34	2.01	1.82	1.62	1.36	1.16	0.95
5.07	4.51	4.07	3.63	3.27	2.84	2.47	2.13	1.92	1.71	1.44	1.23	1.02
5.32	4.74	4.27	3.81	3.44	2.98	2.59	2.24	2.02	1.79	1.51	1.29	1.07
5.57	4.96	4.47	3.98	3.60	3.13	2.72	2.35	2.11	1.88	1.58	1.35	1.13
5.82	5.19	4.67	4.17	3.77	3.27	2.84	2.46	2.21	1.97	1.66	1.42	1.18
6.07	5.41	4.88	4.35	3.93	3.41	2.97	2.57	2.31	2.06	1.73	1.48	1.23
6.32	5.64	5.08	4.53	4.10	3.56	3.10	2.68	2.41	2.15	1.81	1.55	1.28
6.57	5.86	5.29	4.73	4.28	3.84	3.35	2.91	2.63	2.36	1.99	1.72	1.44
6.82	6.08	5.49	4.92	4.43	3.84	3.37	2.91	2.61	2.33	1.96	1.67	1.39
7.07	6.30	5.69	5.11	4.61	4.13	3.60	3.11	2.80	2.50	2.11	1.80	1.50
7.32	6.52	5.89	5.29	4.79	4.28	3.85	3.33	3.00	2.67	2.35	1.93	1.60
7.57	6.74	6.10	5.49	4.97	4.43	4.10	3.55	3.20	2.86	2.40	2.00	1.71
7.82	6.96	6.31	5.69	5.16	4.61	4.26	3.70	3.34	2.99	2.52	2.10	1.81
8.07	7.18	6.51	5.88	5.34	4.78	4.40	3.83	3.46	3.09	2.61	2.18	1.82
8.32	7.40	6.71	6.07	5.52	4.95	4.56	3.98	3.60	3.21	2.70	2.31	1.92
8.57	7.62	6.92	6.27	5.71	5.13	4.73	4.15	3.77	3.37	2.84	2.43	2.02
8.82	7.84	7.13	6.47	5.90	5.32	4.91	4.32	3.93	3.52	3.00	2.56	2.13
9.07	8.06	7.34	6.67	6.09	5.50	5.09	4.49	4.09	3.67	3.14	2.69	2.24
9.32	8.28	7.55	6.87	6.28	5.68	5.26	4.66	4.25	3.82	3.29	2.82	2.37
9.57	8.50	7.76	7.07	6.47	5.87	5.44	4.83	4.41	3.97	3.44	2.96	2.49
9.82	8.72	7.97	7.27	6.66	6.05	5.62	5.00	4.58	4.14	3.60	3.07	2.59
10.07	8.94	8.18	7.47	6.85	6.24	5.80	5.17	4.74	4.29	3.74	3.19	2.70
10.32	9.16	8.39	7.67	7.04	6.42	5.97	5.33	4.89	4.43	3.87	3.32	2.82
10.57	9.38	8.60	7.87	7.23	6.60	6.14	5.49	5.04	4.57	4.00	3.44	2.94
10.82	9.60	8.81	8.07	7.42	6.78	6.31	5.65	5.19	4.71	4.14	3.57	3.06
11.07	9.82	9.02	8.27	7.61	6.96	6.48	5.81	5.34	4.85	4.27	3.69	3.07
11.32	10.04	9.23	8.47	7.80	7.14	6.65	5.97	5.49	5.00	4.41	3.82	3.26
11.57	10.26	9.44	8.67	7.99	7.32	6.82	6.13	5.64	5.14	4.54	3.95	3.34
11.82	10.48	9.65	8.87	8.19	7.51	7.00	6.30	5.79	5.28	4.67	4.07	3.46
12.07	10.70	9.86	9.07	8.38	7.69	7.17	6.46	5.94	5.42	4.80	4.19	3.58
12.32	10.92	10.07	9.27	8.57	7.87	7.35	6.63	6.10	5.57	4.94	4.32	3.69
12.57	11.14	10.28	9.47	8.76	8.05	7.52	6.79	6.25	5.71	5.07	4.44	3.80
12.82	11.36	10.49	9.67	8.95	8.23	7.69	6.95	6.40	5.85	5.20	4.56	3.91
13.07	11.58	10.70	9.87	9.14	8.41	7.86	7.11	6.55	6.00	5.34	4.69	4.03
13.32	11.80	10.91	10.07	9.33	8.59	8.03	7.27	6.70	6.14	5.47	4.81	4.15
13.57	12.02	11.12	10.27	9.52	8.77	8.20	7.43	6.85	6.28	5.60	4.93	4.27
13.82	12.24	11.33	10.47	9.71	8.95	8.37	7.59	7.00	6.42	5.73	5.05	4.38
14.07	12.46	11.54	10.67	9.90	9.13	8.54	7.75	7.16	6.57	5.87	5.18	4.50
14.32	12.68	11.75	10.87	10.11	9.33	8.73	7.93	7.33	6.73	6.03	5.33	4.64
14.57	12.90	11.96	11.07	10.31	9.52	8.91	8.11	7.50	6.89	6.18	5.47	4.75
14.82	13.12	12.17	11.27	10.50	9.70	9.08	8.27	7.65	7.03	6.31	5.59	4.87
15.07	13.34	12.38	11.47	10.69	9.88	9.25	8.43	7.80	7.17	6.44	5.71	5.00
15.32	13.56	12.59	11.67	10.87	10.06	9.42	8.59	7.95	7.31	6.57	5.83	5.11
15.57	13.78	12.80	11.87	11.05	10.23	9.58	8.74	8.09	7.44	6.69	5.94	5.22
15.82	14.00	13.01	12.06	11.23	10.40	9.75	8.90	8.24	7.58	6.82	6.06	5.34
16.07	14.22	13.22	12.25	11.41	10.57	9.91	9.05	8.38	7.71	6.94	6.17	5.45
16.32	14.44	13.43	12.44	11.59	10.74	10.08	9.21	8.53	7.85	7.07	6.29	5.56
16.57	14.66	13.64	12.63	11.76	10.91	10.25	9.37	8.68	8.00	7.21	6.42	5.68
16.82	14.88	13.85	12.82	11.94	11.08	10.42	9.53	8.83	8.14	7.34	6.54	5.79
17.07	15.10	14.05	13.01	12.11	11.25	10.59	9.69	8.98	8.28	7.47	6.66	5.90
17.32	15.32	14.26	13.20	12.29	11.42	10.76	9.85	9.13	8.42	7.60	6.78	6.01
17.57	15.54	14.47	13.39	12.46	11.59	10.93	10.01	9.28	8.56	7.73	6.90	6.13
17.82	15.76	14.68	13.57	12.63	11.76	11.10	10.18	9.44	8.71	7.87	7.03	6.25
18.07	15.98	14.89	13.75	12.80	11.93	11.27	10.34	9.59	8.85	8.00	7.15	6.37
18.32	16.20	15.10	13.93	12.97	12.10	11.44	10.51	9.75	9.00	8.14	7.28	6.49
18.57	16.42	15.31	14.11	13.14	12.27	11.61	10.67	9.90	9.14	8.27	7.40	6.61
18.82	16.64	15.52	14.29	13.31	12.44	11.78	10.83	10.06	9.28	8.40	7.52	6.73
19.07	16.86	15.73	14.47	13.48	12.61	11.95	11.00	10.21	9.42	8.53	7.64	6.85
19.32	17.08	15.94	14.65	13.65	12.78	12.12	11.17	10.37	9.57	8.67	7.76	6.96
19.57	17.30	16.15	14.83	13.82	12.95	12.29	11.34	10.53	9.72	8.81	7.91	7.07
19.82	17.52	16.36	15.01	14.00	13.12	12.46	11.51	10.69	9.88	8.96	8.05	7.18
20.07	17.74	16.57	15.19	14.17	13.29	12.63	11.68	10.85	10.03	9.10	8.18	7.29
20.32	17.96	16.78	15.37	14.34	13.46	12.80	11.85	11.01	10.18	9.24	8.31	7.40
20.57	18.18	16.99	15.55	14.51	13.63	12.97	12.02	11.17	10.33	9.38	8.44	7.51
20.82	18.40	17.20	15.73	14.68	13.80	13.14	12.19	11.34	10.49	9.53	8.58	7.62
21.07	18.62	17.41	15.91	14.85	13.97	13.31	12.36	11.51	10.65	9.68	8.71	7.73
21.32	18.84	17.62	16.09	15.02	14.14	13.48	12.53	11.68	10.81	9.83	8.85	7.84
21.57	19.06	17.83	16.27	15.19	14.31	13.65	12.70	11.85	11.00	10.00	8.99	7.95
21.82	19.28	18.04	16.45	15.36	14.48	13.82	12.87	12.02	11.17	10.15	9.13	8.06
22.07	19.50	18.25	16.63	15.53	14.65	14.00	13.04	12.19	11.34	10.31	9.28	8.17
22.32	19.72	18.46	16.81	15.70	14.82	14.17	13.21	12.36	11.51	10.47	9.43	8.28
22.57	19.94	18.67	16.99	15.87	14.99	14.34	13.38	12.53	11.68	10.63	9.59	8.39
22.82	20.16	18.88	17.17	16.04	15.16	14.51	13.55	12.70	11.85	10.80	9.75	8.50
23.07	20.38	19.09	17.35	16.21	15.33	14.68	13.72	12.87	12.02	11.00	9.94	8.61
23.32	20.60	19.30	17.53	16.38	15.50	14.85	13.89	13.04	12.19	11.17	10.10	8.72
23.57	20.82	19.51	17.71	16.55	15.67	15.02	14.06	13.21	12.36	11.34	10.26	8.83
23.82	21.04	19.72	17.89	16.72	15.84	15.19	14.23	13.38	12.53	11.51	10.43	8.94
24.07	21.26	19.93	18.07	16.89	16.01	15.36	14.40	13.55	12.70	11.68	10.60	9.05
24.32	21.48	20.14	18.25	17.06	16.18	15.53	14.57	13.72	12.87	11.85	10.77	9.16
24.57	21.70	20.35	18.43	17								

TABLE 165.—COPPER NAILS AND RIVETS (continued)

Description.	Gauge.	Length.	Weight per 1,000.	
	No.	Inches.	Lb.	Oz.
Coppersmith's rivets, tinned for hoses—				
" hose No. 1 .	8	$\frac{1}{2}$	4	8
" hose No. 2 .	7	$\frac{7}{16}$	5	12
" hose No. 3 .	7	8	6	8
" hose No. 4 .	7	9	7	4
" hose No. 4 .	7	11	8	4
" washers for do.—				
" hose No. 1 .	...	...	2	4
" hose No. 2 .	...	...	2	12
" hose No. 3 .	...	...	2	12
" hose No. 4 .	...	...	3	4

Brazed Copper tubes weigh more per lineal foot than seamless tubes. An exact general multiple cannot be given, as the proportion of difference varies with the thickness, the diameter and the kind of brazed joint.

Mandrel-drawn brazed Copper tubes weigh the same as Seamless tubes.

TABLE 166.—SHEET LEAD : WEIGHT PER SQUARE FOOT.
Usual size of Sheets, 32 feet x 7 feet.

Weight per Square Foot.		Weight per Square Foot.	
Pounds.	Thickness. Inch.	Pounds.	Thickness. Inch.
2½	·042 or $\frac{1}{24}$	5½	·093 or $\frac{1}{11}$ full
3	·051 or $\frac{1}{20}$ full	6	·101 or $\frac{1}{10}$
3½	·059	6½	·110 or $\frac{1}{9}$
4	·067 or $\frac{1}{15}$ full	7	·118 or $\frac{1}{9}$
4½	·076 or $\frac{1}{13}$	7½	·126 or $\frac{1}{8}$ bare
5	·084 or $\frac{1}{12}$ full	8	·135 or $\frac{1}{8}$ full

TABLE 167.—SHEET LEAD. FRENCH PRACTICE.
Usual size of sheets, 2·80 metres and 3·88 metres wide, 8 to 10 metres long (9 feet 2 inches and 12 feet 9 inches wide, 26 feet to 33 feet long).

Thickness.	Weight per Square Metre.	Thickness.	Weight per Square Metre.
Millimetres.	Kilogrs. or Lbs.	Millimetres.	Kilogrs. or Lbs.
1	11·25 or 24·8	3	34·00 or 75·0
1½	17·00 or 37·5	4	45·40 or 100·1
2	22·70 or 50·1	5	56·80 or 125·2
2½	28·40 or 62·6	7	79·50 or 175·3

AM WIRE GAUGE (The Broughton Copper Co.) (continued).

specific gravity, 8.8917

COPPER.

8	9	10	11	12	13	14	15	16	17	18	19	20
0.165	0.148	0.134	0.120	0.109	0.095	0.083	0.072	0.065	0.058	0.049	0.043	0.038
$\frac{1}{2}$ b	$\frac{1}{2}$ f	$\frac{3}{4}$ b	$\frac{3}{4}$ b	$\frac{3}{4}$ b	$\frac{3}{4}$ f	$\frac{3}{4}$ f	$\frac{3}{4}$ b	$\frac{3}{4}$ f	$\frac{3}{4}$ b	$\frac{3}{4}$ f	$\frac{3}{4}$ b	$\frac{3}{4}$ f
4.19	3.76	3.40	3.05	2.77	2.41	2.11	1.83	1.65	1.47	1.24	1.07	0.89

FOOT IN POUNDS,

13.80	12.35	11.16	9.97	9.04	7.87	6.86	5.94	5.36	4.78	4.08	...	...
14.30	12.80	11.56	10.34	9.37	8.15	7.11	6.16	5.55	4.95	4.18	...	...
14.30	13.25	11.97	10.70	9.70	8.44	7.30	6.33	5.76	5.13	...	...	...
15.30	13.69	12.37	11.04	10.03	8.73	7.61	6.59	5.95	5.30	...	...	...
15.30	14.14	12.78	11.42	10.36	9.02	7.86	6.81	6.14	5.48	...	...	...
16.30	14.59	13.19	11.79	10.69	9.30	8.12	7.03	6.34	5.65	...	...	...
16.30	15.04	13.59	12.15	11.02	9.59	8.37	7.25	6.54	...	...	...	...
17.30	15.48	14.00	12.51	11.35	9.88	8.62	7.47	6.73	...	...	...	...
17.70	15.93	14.40	12.85	11.68	10.16	8.87	7.68	6.93	...	...	...	...
18.29	16.38	14.81	13.24	12.01	10.45	9.12	7.90	7.13	...	...	...	...
18.79	16.83	15.21	13.60	12.34	10.74	9.37	8.12	...	...	...	...	...
19.29	17.27	15.62	13.98	12.67	11.08	9.62	8.34	...	...	...	...	...
19.79	17.72	16.02	14.33	13.00	11.31	9.87	8.55	...	...	...	...	...
20.29	18.17	16.43	14.69	13.38	11.60	10.12	8.77	...	...	...	...	...
20.79	18.62	16.83	15.05	13.76	11.89	10.37	...	...	...	...	...	...
21.29	19.06	17.24	15.42	14.09	12.18	10.63	...	...	...	...	...	...
21.79	19.51	17.64	15.78	14.32	12.46	10.88	...	...	...	...	...	...
22.29	19.96	18.05	16.14	14.65	12.75	11.13	...	...	...	...	...	...
22.79	20.41	18.45	16.51	14.98	13.04	...	...	...	...	...	...	...
23.28	20.86	18.86	16.87	15.31	13.33	...	...	...	...	...	...	...
23.78	21.30	19.26	17.23	15.64	13.61	...	...	...	...	...	...	...
24.28	21.74	19.67	17.59	15.97	13.90	...	...	...	...	...	...	...
24.78	22.19	20.08	17.96	16.30	...	...	...	...	...	...	...	...
25.28	22.63	20.48	18.32	16.63	...	...	...	...	...	...	...	...
25.78	23.07	20.89	18.68	16.96	...	...	...	...	...	...	...	...
26.28	23.51	21.29	19.05	17.29	...	...	...	...	...	...	...	...
26.78	23.95	21.70	19.41	...	...	...	...	...	...	...	...	...
27.28	24.39	22.10	19.77	...	...	...	...	...	...	...	...	...
27.78	24.83	22.51	20.13	...	...	...	...	...	...	...	...	...
28.27	25.27	22.91	20.50	...	...	...	...	...	...	...	...	...
0.56	0.58	0.43	0.35	0.29	0.22	0.17	0.12	0.10	0.08	0.06	0.04	0.03

number given at bottom of column ; for example—The Weight
B. W. G., is $2.78 - 0.29 = 2.49$ lbs. f , full ; b , bare.

TABLE 169.—TIN PLATES, DIMENSIONS AND WEIGHTS
(continued).

Description.	Mark.	Dimensions of Sheets.	Number of Sheets in a Box.	Weight of each Box.
			Inches.	Pounds.
Four crosses No. 1 . . .	IXXXX	12 × 12	225	199
Common doubles . . .	DC	17 × 12 $\frac{1}{2}$	100	94
Cross doubles . . .	DX	17 × 12 $\frac{1}{2}$	100	122
Two cross doubles . . .	DXX	17 × 12 $\frac{1}{2}$	100	143
Three cross doubles . . .	DXXX	17 × 12 $\frac{1}{2}$	100	164
Four cross doubles . . .	DXXXX	17 × 12 $\frac{1}{2}$	100	185
Common doubles . . .	DC	17 × 25	50	94
Cross doubles . . .	DX	17 × 25	50	122
Two cross doubles . . .	DXX	17 × 25	50	143
Three cross doubles . . .	DXXX	17 × 25	50	164
Four cross doubles . . .	DXXXX	17 × 25	50	185
Common doubles . . .	DC	34 × 25	25	94
Cross doubles . . .	DX	34 × 25	25	122
Two cross doubles . . .	DXX	34 × 25	25	143
Three cross doubles . . .	DXXX	34 × 25	25	164
Four cross doubles . . .	DXXXX	34 × 25	25	185
Small common doubles . . .	SDC	15 × 11	200	167
Small cross doubles . . .	SDX	15 × 11	200	188
Small two cross doubles . . .	SDXX	15 × 11	200	209
Small three cross doubles . . .	SDXXX	15 × 11	200	230
Small four cross doubles . . .	SDXXXX	15 × 11	200	251
Small common doubles . . .	SDC	15 × 22	100	167
Small cross doubles . . .	SDX	15 × 22	100	188
Small two cross doubles . . .	SDXX	15 × 22	100	209
Small three cross doubles . . .	SDXXX	15 × 22	100	230
Small four cross doubles . . .	SDXXXX	15 × 22	100	251

Note.—The weights of the cross-marked boxes advance at the rate of 21 pounds per Cross.

TABLE 170.—BLOCK TIN PIPES: WEIGHT PER YARD.

Bores	$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1 inch
Weights	7, 9, 11, 14, 17, 23, 30, 38, 48 ounces.

TABLE 163.—COPPER NAILS AND RIVETS. SIZE AND WEIGHT.

Description.	Gauge.	Length.	Weight	
			per 1,000	
	No.	Inches.	Lb.	Oz.
Copper nails, wrought, clench, flat-	13	1	2	2
head, full countersunk	13	1 $\frac{1}{8}$	2	10
"	12	1 $\frac{1}{4}$	4	8
"	11	1 $\frac{1}{2}$	6	8
"	13	1 $\frac{3}{4}$	4	12
"	11	1 $\frac{3}{4}$	7	10
"	11	2	8	8
"	10	2 $\frac{1}{2}$	12	12
"	11	2 $\frac{3}{8}$	10	0
"	11	2 $\frac{1}{2}$	10	10
"	9	2 $\frac{1}{2}$	17	12
"	9	2 $\frac{3}{4}$	19	4
"	8	3	25	8
"	8	3 $\frac{1}{4}$	28	0
"	8	3 $\frac{1}{2}$	29	12
"	7	3 $\frac{3}{4}$	36	0
"	6	4	48	0
"	6	4 $\frac{1}{2}$	55	4
"	4	5	82	12
"	3	5 $\frac{1}{2}$	108	0
"	3	6	119	0
"	4	6	107	12
"	3	7	136	12
"	3	7 $\frac{1}{2}$	146	4
"	2	8	189	0
"	2	8 $\frac{1}{2}$	199	0
Spike die-heads, with flat points	12	1 $\frac{1}{2}$	4	12
"	10	1 $\frac{1}{4}$	9	8
"	9	2	12	0
"	7	2 $\frac{1}{2}$	19	10
"	6	3	30	0
"	4	3 $\frac{1}{2}$	48	0
"	2	4 $\frac{1}{2}$	84	8
Rose-heads, with flat points	14	1 $\frac{3}{4}$	1	0
"	13	1	2	4
"	13	1 $\frac{1}{4}$	3	0
"	12	1 $\frac{1}{2}$	4	6
"	10	1 $\frac{3}{8}$	9	8
"	10	2	19	2

TABLE 172—ZINC SHEETS: ACCORDING TO THE ENGLISH ZINC GAUGE.

(London Zinc Mills.)

Gauge	Approximate Weight per Square Foot	The tenths of an Inch.	1 ft. x 2 ft. 6 in.		2 ft. x 3 ft.		3 ft. x 3 ft.		Nearest Birmingham Wire Gauge
			Approximate Weight per Sheet	Approximate Number of Sheets in 10 Cwt	Approximate Weight per Sheet	Approximate Number of Sheets in 10 Cwt	Approximate Weight per Sheet	Approximate Number of Sheets in 10 Cwt	
1	0.004	0.004	2 10	427					41
2	0.006	0.006	2 13	294					38
3	0.007	0.007			4 15	227			37
4	0.008	0.008			6 4	180			34
5	0.010	0.010			7 9	148			31
6	0.011	0.011	7 14	142	8 14	126	10 2	113	30
7	0.013	0.013	9 1	124	10 3	110	11 10	96	29
8	0.015	0.015	10 8	107	11 11	95	13 8	83	28
9	0.017	0.017	11 11	96	13 2	85	15 0	75	27
10	0.019	0.019	12 7	89	15 2	74	17 4	65	25
11	0.021	0.021	15 3	74	17 1	66	19 8	57	24
12	0.025	0.025	17 8	64	19 11	57	22 8	50	23
13	0.028	0.028			22 5	50	25 8	44	22
14	0.031	0.031			24 15	45	28 8	39	21
15	0.036	0.036			28 14	39	33 0	34	20
16	0.041	0.041			32 13	34	37 8	30	19
17	0.046	0.046			36 12	30	42 0	27	18
18	0.051	0.051			40 11	28	46 8	24	
19	0.056	0.056			45 15	24	52 8	21	17
20	0.063	0.063			51 8	22	58 8	19	16
21	0.072	0.072			56 7	20	64 8	17	15

Sheets thicker than above are rolled to Birmingham Wire Gauge.

WIRE ROPES. See STRENGTH OF MATERIALS (pp. 389-400).

CHAINS AND CHAIN CABLES. See STRENGTH OF MATERIALS (pp. 400-408).

TABLE 165 COPPER NAILS AND RIVETS (*continued*)

Description.	Gauge.	Length.	Weight per 100
	No.	Inches.	Lb.
Coppersmith's rivets, tinned for hoses.—			
hose No. 1 .	8	$\frac{3}{8}$	4
hose No. 2 .	7	$\frac{7}{8}$	5
hose No. 3 .	7	8	6
hose No. 4 .	7	9	7
hose No. 4 .	7	11	8
washers for do.—			
hose No. 1 .	...	.	2
hose No. 2 .	..	...	2
hose No. 3 .	...	.	2
hose No. 4 .	...	...	3

Brazed Copper tubes weigh more per linear foot than seamless tubes. An exact general multiple cannot be given, as proportion of difference varies with the thickness, the diameter and the kind of brazed joint.

Mandrel-drawn brazed Copper tubes weigh the same as seamless tubes.

TABLE 166.—SHEET LEAD, WEIGHT PER SQUARE FOOT.
Usual size of Sheets, 32 feet x 7 feet.

Weight per Square Foot.	Thickness.	Weight per Square Foot.	Thickness.
Pounds.	Inch.	Pounds.	Inch.
$2\frac{1}{2}$	0.42 or $\frac{1}{24}$	$5\frac{1}{2}$	.093 or $\frac{1}{11}$ full
3	.051 or $\frac{1}{20}$ full	6	.101 or $\frac{1}{10}$
$3\frac{1}{2}$	.059	$6\frac{1}{2}$	.110 or $\frac{1}{9}$
4	.067 or $\frac{1}{15}$ full	7	.118 or $\frac{1}{8}$
$4\frac{1}{2}$	.076 or $\frac{1}{13}$	$7\frac{1}{2}$	.126 or $\frac{1}{8}$ bare
5	.084 or $\frac{1}{12}$ full	8	.135 or $\frac{1}{8}$ full

TABLE 167.—SHEET LEAD, FRENCH PRACTICE.
Usual size of sheets, 2.50 metres and 3.88 metres wide, 8 to 10 metres long (10 feet 2 inches and 12 feet 9 inches wide, 26 feet to 33 feet long).

Thickness.	Weight per Square Metre.	Thickness.	Weight per Square Metre.
Millimetres.	Kil. grs. or Lbs.	Millimetres.	Kil. grs. or Lbs.
1	11.25 or 24.8	3	34.0 or 75.0
$1\frac{1}{2}$	17.00 or 37.5	4	45.40 or 100.1
2	22.70 or 50.1	5	56.80 or 125.2
$2\frac{1}{2}$	28.40 or 62.6	7	79.30 or 175.0

TABLE 172—ZINC SHEETS: ACCORDING TO THE ENGLISH ZINC GAUGE.

(London Zinc Mills.)

Gauge No.	Approximate Weight per Square Foot	Thousandths of an Inch	7 ft. x 2 ft. x 10.		7 ft. x 3 ft.		8 ft. x 3 ft.		Nearest Birmingham Wire Gauge
			Approximate Weight per Sheet	Approximate Number of Sheets in 10 cwt	Approximate Weight per Sheet	Approximate Number of Sheets in 10 cwt	Approximate Weight per Sheet	Approximate Number of Sheets in 10 cwt	
1	21	004	2 10	427					41
2	24	006	3 13	304					33
3	27	007			4 5	227			37
4	30	008			6 4	180			34
5	33	010			7 9	148			31
6	36	011	7 14	142	8 14	126	10 2	113	30
7	39	013	9 1	124	10 3	110	11 10	96	29
8	42	015	10 8	107	11 13	95	12 8	83	28
9	45	017	11 11	96	13 2	85	15 0	75	27
10	48	019	12 7	88	15 2	74	17 4	65	26
11	51	021	15 3	74	17 1	66	19 8	57	24
12	54	025	7 8	64	19 11	57	22 5	50	23
13	57	028			22 9	50	25 8	44	22
14	60	031			24 15	45	28 8	39	21
15	63	036			28 14	39	33 0	34	20
16	66	041			32 13	34	37 8	30	19
17	69	046			36 12	30	42 0	27	18
18	72	051			40 11	28	46 8	24	
19	75	056			45 15	24	52 8	21	17
20	78	065			51 3	22	58 8	19	16
21	81	072			56 7	20	64 8	17	15

Sheets thicker than above are rolled to Birmingham Wire Gauge.

WIRE ROPES. See STRENGTH OF MATERIALS (pp. 38—400).

CHAINS AND CHAIN CABLES. See STRENGTH OF MATERIALS (pp. 400—408).

TABLE 168.—SOLID DRAWN LEAD PIPES (*continued*).

DRAWN SQUARE SOIL PIPE.			
Bore	Length	Weights of One Length for Various Thicknesses	
Inches.	Feet.	Pounds.	
$3\frac{1}{2} \times 3\frac{1}{2}$	10	60, 80	
4×4	10	80, 100	

COMPOSITION PIPE (Lead and Tin)							
Diameters, inches . . .	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	About 1 cwt. each coil.
Average length of coils, feet . . .	670,	240,	220	170,	150,	120,	
Diameters, inches . . .	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1, 1 $\frac{1}{4}$	
Average length of coils, feet . . .	100,	90,	70,	70,	60,	50,	40

TABLE 169.—TIN PLATES, DIMENSIONS AND WEIGHTS.

Description.	Mark.	Dimen- sions of Sheets.	Number of Sheets in a Box	Weight of one Box.	
				Inches.	Pounds.
Common No. 1 . . .	IC	14×10	225		108
Cross No. 1 . . .	IX	14×10	225		136
Two crosses No. 1 . . .	IXX	14×10	225		157
Three crosses No. 1 . . .	IXXX	14×10	225		178
Four crosses No. 1 . . .	IXXXX	14×10	225		199
Common No. 1 . . .	IC	14×20	112		108
Cross No. 1 . . .	IX	14×20	112		136
Two crosses No. 1 . . .	IXX	14×20	112		157
Three crosses No. 1 . . .	IXXX	14×20	112		178
Four crosses No. 1 . . .	IXXXX	14×20	112		199
Common No. 1 . . .	IC	28×20	56		108
Cross No. 1 . . .	IX	28×20	56		136
Two crosses No. 1 . . .	IXX	28×20	56		157
Three crosses No. 1 . . .	IXXX	28×20	56		178
Four crosses No. 1 . . .	IXXXX	28×20	56		199
Common No. 1 . . .	IC	12×12	225		108
Cross No. 1 . . .	IX	12×12	225		136
Two crosses No. 1 . . .	IXX	12×12	225		157
Three crosses No. 1 . . .	IXXX	12×12	225		178

TABLE 172.—ZINC SHEETS: ACCORDING TO THE ENGLISH ZINC GAUGE.

(London Zinc Mills.)

Gauge No.	Approximate Weight per Square Foot	Thickness in inch	7 ft. x 8 ft.		7 ft. x 6 ft.		5 ft. x 8 ft.		Nearest Birmingham Wire Gauge
			Approximate Number of Sheets in 10 Cwt	Weight per Sheet	Approximate Number of Sheets in 10 Cwt	Weight per Sheet	Approximate Number of Sheets in 10 Cwt	Weight per Sheet	
	Oz.			Lbs. Oz.		Lbs. Oz.		Lbs. Oz.	
1	23	.004	427	2 10					41
2	34	.006	294	3 13					38
3	38	.007			4 15	227			37
4	45	.008			5 4	180			34
5	52	.010			7 9	148			31
6	63	.011	142	7 14	8 14	128	10 2	111	30
7	73	.013	124	9 1	10 3	110	11 10	96	29
8	9	.015	107	10 8	11 13	95	15 8	83	28
9	10	.017	96	11 11	13 2	85	15 9	75	27
10	11½	.019	89	13 7	15 9	74	17 4	65	25
11	13	.021	74	15 3	17 1	66	19 8	57	24
12	15	.025	64	17 8	19 11	57	22 8	50	23
13	17	.028			22 5	50	25 8	44	22
14	19	.031			24 15	45	28 8	39	21
15	22	.036			26 14	39	30 0	34	20
16	25	.041			32 18	34	37 8	30	19
17	28	.046			36 12	30	42 0	27	18
18	31	.051			40 11	28	46 8	24	
19	35	.059			45 15	24	52 8	21	17
20	39	.065			51 3	22	58 8	19	16
21	43	.072			56 7	20	64 8	17	15

Sheets thicker than above are rolled to Birmingham Wire Gauge.

WIRE ROPES. See STRENGTH OF MATERIALS (pp. 386—400).

CHAINS AND CHAIN CABLES. See STRENGTH OF MATERIALS (pp. 400—408).

TABLE 164.—WEIGHT OF SEAMLESS BRASS TUBES, CONTAINING 70% OF COPPER AND 30% OF ZINC
(The Brougham Copper Company) BIRMINGHAM WIRE GAUGE

[illegible]

2 1/2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
51.0	4.54	4.08	3.77	3.41	3.11	2.80	2.56	2.25	1.97	1.72	1.56	1.40	...	...	...	...	...	...
57.1	4.84	4.34	4.01	3.62	3.30	2.98	2.72	2.38	2.09	1.83	1.65	1.48	...	...	...	...	...	...
60.3	5.02	4.60	4.25	3.84	3.50	3.17	2.88	2.52	2.21	1.93	1.75	1.56	...	...	...	...	...	...
63.5	5.18	4.80	4.49	4.05	3.69	3.33	3.03	2.66	2.34	2.04	1.84	1.65	...	...	...	...	...	...
66.7	5.33	5.12	4.78	4.27	3.89	3.50	3.19	2.80	2.46	2.14	1.91	...	...	...	...	...	...	...
69.8	5.48	5.23	4.90	4.44	4.04	3.67	3.35	2.94	2.58	2.24	2.03	...	...	...	...	...	...	...
73.0	5.60	5.32	5.05	4.70	4.28	3.85	3.51	3.07	2.70	2.35	2.13	...	...	...	...	...	...	...
76.2	5.72	5.41	5.11	4.74	4.31	3.87	3.51	3.07	2.69	2.33	2.11	...	...	...	...	...	...	...
79.3	5.84	5.51	5.19	4.81	4.37	3.92	3.55	3.10	2.71	2.35	2.12	...	...	...	...	...	...	...
82.5	5.96	5.61	5.27	4.88	4.43	3.97	3.59	3.13	2.73	2.37	2.14	...	...	...	...	...	...	...
85.7	6.08	5.71	5.36	4.96	4.50	4.03	3.64	3.17	2.76	2.40	2.17	...	...	...	...	...	...	...
88.9	6.20	5.81	5.45	5.04	4.57	4.09	3.69	3.21	2.79	2.42	2.19	...	...	...	...	...	...	...
92.0	6.32	5.91	5.54	5.12	4.64	4.15	3.74	3.25	2.82	2.44	2.21	...	...	...	...	...	...	...
95.2	6.44	6.01	5.63	5.20	4.71	4.21	3.79	3.29	2.85	2.46	2.23	...	...	...	...	...	...	...
98.4	6.56	6.11	5.72	5.28	4.78	4.27	3.84	3.33	2.88	2.48	2.25	...	...	...	...	...	...	...
101.6	6.68	6.21	5.81	5.36	4.85	4.33	3.89	3.37	2.91	2.50	2.27	...	...	...	...	...	...	...
112	6.99	6.74	6.41	6.04	5.64	5.23	4.80	4.36	3.90	3.42	3.08	2.79	2.48	2.29	2.08	1.86	1.67	1.48

Note. If the internal diam. is 2 in., add figure at top of column, for example. The weight per foot of a Brass Tube is 2.48 times internal diameter, 12 lb. Wt. is 2.40 + 0.27 = 2.67 lb. $\frac{1}{2}$ full, $\frac{1}{4}$ bare.

Wt. of per cent.	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Wt. of per cent.	96.5	94.8	93.1	91.4	89.7	88.0	86.3	84.6	82.9	81.2	79.5	77.8	76.1	74.4	72.7	71.0

These tables show the relative weights of Brass Tubes made to the Imperial Wire Gauge, and the Birmingham Wire Gauge, the latter being taken at 100.

TABLE 165.—COPPER NAILS AND RIVETS, SIZE AND WEIGHT.

Description.	Gauge. Length.		Weight per 100
	No.	Inches.	
Copper nails, wrought, clenched, flat head, full countersunk	13	1	2
"	13	1 $\frac{1}{4}$	2
"	12	1 $\frac{1}{2}$	2
"	11	1 $\frac{3}{4}$	6
"	13	1 $\frac{3}{4}$	4
"	11	1 $\frac{3}{4}$	4
"	11	2	5
"	10	2 $\frac{1}{4}$	12
"	11	2 $\frac{1}{4}$	10
"	11	2 $\frac{1}{2}$	10
"	9	2 $\frac{1}{2}$	17
"	9	2 $\frac{3}{4}$	15
"	8	3	24
"	8	3 $\frac{1}{2}$	24
"	8	3 $\frac{1}{2}$	24
"	7	3 $\frac{3}{4}$	30
"	6	4	40
"	6	4 $\frac{1}{2}$	50
"	4	5	82
"	3	5 $\frac{1}{2}$	100
"	3	6	110
"	4	6	101
"	3	7	130
"	3	7 $\frac{1}{2}$	140
"	2	8	180
"	2	8 $\frac{1}{2}$	190
Spike die-heads, with flat points	12	1 $\frac{1}{2}$	4
"	10	1 $\frac{3}{4}$	5
"	9	2	12
"	7	2 $\frac{1}{2}$	16
"	6	3	30
"	4	3 $\frac{1}{2}$	40
"	2	4 $\frac{1}{2}$	84
Rose heads, with flat points	14	1	2
"	13	1	2
"	13	1 $\frac{1}{4}$	3
"	12	1 $\frac{1}{2}$	4
"	10	1 $\frac{3}{4}$	5
"	10	2	7

TABLE 165.—COPPER NAILS AND RIVETS (*continued*).

Description.	Gauge.	Length, Inches.	Weight per 1,000.	
			Lb.	Oz.
Rose-heads, with flat points . . .	No. 8	2½	16	14
" " " " " "	8	2½	19	8
" " " " " "	6	3	30	0
" " " " " "	5	3½	42	8
" " " " " "	4	4	53	12
" " " " " "	3	4½	71	0
" " " " " "	2	5	93	0
Clasp . . . . .	...	2½	13	0
" " " " " "	...	2	9	0
" " " " " "	...	1½	4	0
" " " " " "	...	1½	2	10
" " " " " "	...	1	1	12
" " " " " "	...	1½	...	...
Cut copper nails, brads, billed . . .	...	...	0	10
" " " " " "	...	...	0	12
" " " " " "	...	1	1	10
" " " " " "	...	1½	2	4
" " " " " "	...	1½	3	12
" " " " " "	...	1½	5	8
Lightning conductor, countersunk (	6	1½	10	8
heads, and flat points, jagged . . .	5	1½	15	0
" " " " " "	4	2	18	8
" " " " " "	3	2½	26	0
" " " " " "	1	2½	40	0
" " " " " "	1	3	52	0
Scarf tacks, square flat-heads, with (	16	½	0	9
sharp points	16	...	0	11
" " " " " "	16	¾	1	1
" " " " " "	15	1	1	6
Slating . . . . .	...	1½	...	...
Coppersmith's rivets, flat pan-head.	2	1½	22	4
" " " " " "	4	1½	18	12
" " " " " "	6	1½	9	12
" " " " " "	7	1½	6	14
" " " " " "	10	1½	3	0
" " " " " "	11	1½	2	4
" " " " " "	12	1½	1	4
" " " " " "	Inches.	1½	118	0
.. snap-heads	2½	1½	91	0
" " " " " "	1½	1½	78	0
" " " " " "	1½	1½	102	0
" " " " " "	1½	1½	55	71

2. Rectangular beam, of uniform strength, breadth uniform, depth parabolic : load at the middle.

$$D = \frac{Wl^3}{311bd^2E} \quad (23)$$

3. Rectangular beam, of uniform section : load at the middle.

$$D = \frac{Wl^3}{447bd^2E} \quad (24)$$

4. Rectangular beam, of uniform strength ; depth uniform, uniformly loaded.

$$D = \frac{Wl^3}{933bd^2E} \quad (25)$$

5. Rectangular beam, of uniform strength, breadth uniform, elliptic in depth : uniformly loaded.

$$D = \frac{Wl^3}{747bd^2E} \quad (26)$$

6. Rectangular beam, of uniform section, uniformly loaded.

$$D = \frac{Wl^3}{747bd^2E} \quad (27)$$

Deflection of Double-flanged or Hollow Rectangular Beams, Equal Flanges.

7. Double-flanged beam, of uniform strength ; uniform depth, double-triangular in breadth, load at the middle.

Case 1. When the strength of both the flanges and the web is calculated :

$$D = \frac{Wl^3}{4d''^2E(4a + 1.167a'')} \quad (28)$$

d'' = distance apart between centres of flanges

a = sectional area of one flange.

a'' = sectional area of the web, reckoned equal in height to d'' .

From this equation it is inferred that the deflection varies inversely as a power of the depth greater than the square, and less than the cube.

Case 2. When the strength of the flanges alone is calculated.—

$$D = \frac{Wl^3}{16ad''^2E} \quad (29)$$

8. Double-flange beam, of uniform strength, of uniform breadth, triangular in depth; loaded at the middle (figs. 66, 67).

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{2d''^2 E(4a + 1.167u'')} \quad (30)$$

Case 2. When the strength of the flanges alone is calculated :—

$$D = \frac{Wl^3}{8ad''^2 E} \quad (31)$$

9. Double-flange beam, of uniform section, loaded at the middle. See No. 7, formulæ 28 and 29.

10. Double-flange beam, of uniform strength, of uniform depth, breadth parabolic; uniformly loaded.

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{8d''^2 E(4a + 1.167a'')} \quad (32)$$

Case 2. When the strength of the flanges only is calculated :—

$$D = \frac{Wl^3}{32ad''^2 E} \quad (33)$$

11. Double-flange beam, of uniform strength, of uniform breadth, depth parabolic; uniformly loaded (fig. 70).

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{5.33d''^2 E(4a + 1.167a'')} \quad (34)$$

Case 2. When the strength of the flanges only is calculated :—

$$D = \frac{Wl^3}{21.33ad''^2 E} \quad (35)$$

12. Double-flange beam, of uniform section, uniformly loaded.

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{6.4d''^2 E(4a + 1.167a'')} \quad (36)$$

TABLE 173.—ULTIMATE STRENGTH OF COLUMNS OF VARIOUS CONSTRUCTION, WITH FLAT ENDS.

Description of Column.	Formula.	Authority.
1. Round cast-iron, solid or hollow . . .	$W = \frac{36a}{1 + \frac{r^2}{400}}$	Gordon.
2. Rectangular cast-iron, solid or hollow . . .	$W = \frac{36a}{1 + \frac{r^2}{500}}$	Gordon.
3. Rectangular wrought-iron, solid . . .	$W = \frac{16a}{1 + \frac{r^2}{3000}}$	Stoney.
4. Angle, tee, channel, or cruciform iron . . .	$W = \frac{19a}{1 + \frac{r^2}{900}}$	Unwin.
5. Solid round, mild steel . . .	$W = \frac{3a}{1 + \frac{r^2}{1400}}$	Baker.
6. Solid round, strong steel . . .	$W = \frac{51a}{1 + \frac{r^2}{900}}$	Baker.
7. Solid rectangular, mild steel . . .	$W = \frac{30a}{1 + \frac{r^2}{2480}}$	Baker.
8. Solid rectangular, strong steel . . .	$W = \frac{51a}{1 + \frac{r^2}{1000}}$	Baker.

W = breaking weight, in tons.

a = sectional area of the material, in square inches.

r = ratio of length to diameter. The diameter for calculation is the shortest diameter of the section.

Transverse Strength of Railway Rails.

The ordinary double head rail, having heads of equal form and size, may be separated into the web for the whole depth and the flange or overhanging portion. The sectional area

the flange portions can be ascertained by dividing them into narrow horizontal strips, calculating the area of each strip separately, and taking the sums.

Transverse strength of a double-head rail.

$$W = \frac{s(4a' \frac{d''^2}{d} + 1.167t'd^2)}{l} \quad (48)$$

W = breaking weight at the middle, in tons.

a' = net sectional area of one flange, in inches (excluding the central portion pertaining to the web).

d = total depth of the rail, in inches.

d'' = vertical distance apart of the centres of the flanges.

t' = thickness of the web.

l = length of span, between supports, in inches.

s = ultimate tensile strength, in tons per square inch.

Strength of Steel Springs.

The elasticity or deflection of laminated springs, with the working strength, are given by the following formulæ:—

$$E = \frac{1.66l^3}{bt^3n} \quad (49)$$

$$s = \frac{bt^2n}{11.3l} \quad (50)$$

$$n = \frac{1.66l^3}{Ebt^3} \quad (51)$$

E = elasticity, or deflection, in sixteenths of an inch per ton of load.

s = working strength, or load, in tons.

l = span, when loaded, in inches.

b = breadth of plates, in inches, taken as uniform.

t = thickness of plates, in sixteenths of an inch.

n = number of plates.

Note.—The span and the elasticity are those due to the spring when weighted.

2. When extra thick back and short plates are used, they must be replaced by an equivalent number of plates of the ruling thickness, prior to the employment of the formulæ 49 and 50. This is found by multiplying the number of extra thick plates by the cube of their thickness, and dividing the cube of the ruling thickness. Conversely, the number of plates of the ruling thickness given by formula 51, req.

to be deducted and replaced by a given number of extra thick plates, are found by the same calculation.

3. It is assumed that the plates are similarly and regularly formed, and that they are of uniform breadth, and but slight taper at the ends.

Helical Steel Springs.

$$E = \frac{d^3 w}{CD^4} \quad (51)$$

E = compression or extension of one coil, in inches.

d = diameter from centre to centre of steel bar constituting the spring, in inches.

w = weight applied, in pounds.

D = diameter, or side of the square, of the steel bar, in sixteenths of an inch.

C = a constant, which may be taken as 22 for round steel and 30 for square steel.

Note—The deflection E for one coil is to be multiplied by the number of free coils, to obtain the total deflection for given spring.

The relation between the safe load, size of steel, and diameter of coil, may be taken for practical purposes as follows:—

$$D = \sqrt[3]{\frac{wd}{3}}, \text{ for round steel} \quad (52)$$

$$D = \sqrt[3]{\frac{wd}{4.29}}, \text{ for square steel} \quad (53)$$

STRENGTH OF TIMBER.

From the results of Mr. Laslett's experiments, the Table 17 of the direct ultimate tensile and compressive strengths of timbers has been compiled. For tensile strengths, the specimens were 2 inches square, and usually had a clear length of 30 inches. For compressive or crushing strength, the specimens were cubes of from 1 inch to 4 inches, and pieces 2 inches square and upwards, of various lengths. The crushing resistance of 1-inch, 2-inch, 3-inch, and 4-inch cubes of various woods, was practically the same per square inch of the upper surface, though there was a slight difference in favour of the smaller cubes.

TABLE 174.—TENSILE AND COMPRESSIVE STRENGTH OF
TIMBER.

Woods.	Specific Gravity.	Tensile Resistance per Square Inch.	Crushing Resistance per Square Inch.
	Water = 1.	Tons.	Tons.
Oak, English	·858, 893	1·713, 3·380	3·337
„ French	·976	3·617	3·547
„ Dantzic	·838	1·882	3·344
„ American White	·969	3·143	2·709
„ African (or Teak)	·971	3·148	...
Teak, Moulmein	·777	1·474	2·559
Iron Wood, Burmah	1·176	4·311	5·208
Greenheart	1·141	3·937	6·438
Sabicu	·917	2·481	3·776
Mahogany, Spanish	·765	1·692	2·863
„ Honduras	·659	1·338	2·853
Eucalyptus, Tewart	1·169	4·591	4·174
„ Mahogany	·996	1·312	3·198
„ Iron Bark	1·150	3·740	4·601
„ Blue Gum	1·049	2·700	3·078
Ash, English	·750	1·687	3·109
„ Canadian	·588	2·453	2·453
Beech	·705	2·166	...
Elm, English	·642	2·437	2·583
„ Rock, Canada	·748	4·100	3·832
Hornbeam	·819	2·860	3·711
Fir, Dantzic	·603	1·442	3·102
„ Riga	·553	1·808	2·342
„ Spruce	·484	1·756	2·166
Larch, Russia	·649	1·876	2·596
Cedar	·469	1·281	2·000
Red Pine	·553	1·207	2·537
Yellow Pine	·551	1·120	1·877
Pitch Pine	·659	2·083	2·885
Kauri Pine	·544	1·803	2·867

The elastic tensile strength of timber is equal to, or nearly equal to, the ultimate tensile strength. Of Baltic timber, the elastic compressive strength is from 80 per cent. to 90 per cent. of the ultimate compressive resistance.

Columns of Timber.

From observations of the crushing resistance of columns of

wood, Mr. Laslett deduced that the maximum resistance of square pieces to compression is exerted when the sectional area in square inches is to the length in inches proportionally as 4 is to 5 for equal seasoning and equal specific gravities. In this ratio, the maximum resistance to crushing of 12-inch square balks on end, would be exerted for a length of 15 feet.

Timber Piles.

TABLE 175. ULTIMATE STRENGTH OF TIMBER COLUMNS
(Brereton and Stoney.)

Ratio of Length to Least Breadth	Ultimate Weight that can be borne per Square Foot of Section	Ratio of Length to Least Breadth	Ultimate Weight that can be borne per Square Foot of Section
	Tons.		Tons.
10	120	35	84
15	118	40	80
20	117	45	77
25	100	50	75
30	90		

Transverse Strength of Timber Beams, of Large Scantling supported at the Ends, Loaded at the Middle.*

$$\text{Fir} \quad W = \frac{1.78bd^2}{l} \quad (54)$$

$$\text{Red pine} \quad W = \frac{1.39bd^2}{l} \quad (55)$$

$$\text{Quebec yellow pine} \quad W = \frac{1.39bd^2}{l} \quad (56)$$

$$\text{Pitch pine} \quad W = \frac{2.12bd^2}{l} \quad (57)$$

$$\text{English oak} \quad W = \frac{1.64bd^2}{l} \quad (58)$$

$$\text{French oak} \quad W = \frac{2.21bd^2}{l} \quad (59)$$

W = breaking weight in tons.

b = breadth in inches.

d = depth in inches.

l = span in inches.

* *Manual of Rules, Tables and Data*, page 350.

**Deflection of Timber Beams of large Scantling, supported
at the Ends, loaded at the Middle**

$$\text{Fir} \quad D = \frac{Wl^3}{bd^3} \quad (59)$$

$$\text{Red pine} \quad D = \frac{Wl^3}{2434bd^3} \quad (60)$$

$$\text{Quebec yellow pine} \quad D = \frac{Wl^3}{2084bd^3} \quad (61)$$

$$\text{Pitch pine} \quad D = \frac{Wl^3}{2968bd^3} \quad (62)$$

$$\text{English oak} \quad D = \frac{Wl^3}{1848bd^3} \quad (63)$$

$$\text{French oak} \quad D = \frac{Wl^3}{2656bd^3} \quad (64)$$

STRENGTH OF CAST-IRON.

The strength of cast-iron varies according to the distribution and massiveness of the metal. Thicker pieces are less strong than thinner pieces—an inequality which arises from the fact that the outer portions, at and near the surface of a casting, are denser, harder, and stronger than the central portions.

The tensile strength of cast-iron may be taken generally as equal to from 6 tons to 7 tons per square inch of section. Dr. Anderson deduced an average of 6 tons from a long series of tests. Mr. Hodgkinson, comparing the tensile strengths of bars of cast-iron 1 inch, 2 inches, and 3 inches square, found that they were relatively, per square inch, as 100, 66, and 60.

The ultimate compressive strength of cast-iron was determined by Mr. Hodgkinson to average $38\frac{1}{2}$ tons per square inch.

The tensile strength of cast-iron is increased by re-melting. [Sir Frederick Bramwell] proved that the tensile strength of Acadian iron was increased from $7\frac{1}{2}$ tons to $18\frac{1}{2}$ tons by 8 hours of continued fusion and re-melting. The compressive strength averaged $3\frac{1}{2}$ times the tensile strength. Sir Wm. Fairbairn increased the compressive strength of Eglinton hot-blast iron from 44 tons to 88 tons per square inch.

Cast-iron under tension or compression does not have a well-defined elastic limit. Mr. Hodgkinson tested square bars of cast-iron, 10 feet long, under a load in tension, the bar extended $\frac{1}{1000}$ th part of its length; under the same load in compression, the bar extended $\frac{1}{500}$ th its length. In round numbers, it may be taken that extension and elastic compression are each approximately $\frac{1}{1000}$ th part of the length, under a stress of 5 tons per square inch, or $\frac{1}{500}$ th part of the length per ton per square inch, more than twice the rate of elastic extension of iron.

Influence of high temperature.

Cast-iron of average quality loses strength when above 120° F.; and it becomes insecure at the freezing point. At a red heat, its normal strength is reduced one-third.

Malleable cast-iron.

Cast-iron is rendered malleable by the extraction of the constituent carbon, approximating it to wrought iron. The tensile strength of annealed malleable cast-iron is equivalent to over 25 tons per square inch; and 10 tons per square inch is borne without distortion.

Columns.

TABLE 176.—SAFE LOAD ON HOLLOW CAST-IRON COLUMNS WITH FLAT ENDS AND BASE PLATES: LENGTH 30 DIAMETERS.

(Shields.)

Thickness.	Load per Square Inch of Sectional Metal.	
	Length 20 to 24 Diameters.	25 to 30 Diameters.
Inch.	Tons.	Tons.
$\frac{3}{4}$ and upwards	2	$1\frac{1}{2}$
$\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$
$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$
$\frac{3}{8}$	$1\frac{1}{4}$	1

(Load, two tons per square inch of sectional area.)

IRON EXTERNAL DIAMETER OF COLUMNS, IN INCHES												
Thick- ness of Metal	8			11			13			15		
	Area, sq. ins.	Weight per lineal foot	Safe Load, tons	Area, sq. ins.	Weight per lineal foot	Safe Load, tons	Area, sq. ins.	Weight per lineal foot	Safe Load, tons	Area, sq. ins.	Weight per lineal foot	Safe Load, tons
1 1/8	7.07	11.2	14.1	7.85	12.7	15.7	10.99	14.0	22.0	12.57	39.6	25.1
1 1/4	7.28	11.8	14.6	8.81	13.8	17.7	12.76	14.2	25.5	14.73	46.4	29.6
1 1/2	7.68	12.5	15.4	9.37	14.5	18.4	14.14	14.5	26.9	16.49	51.9	33.6
1 3/4	8.17	13.3	16.3	10.06	15.4	19.4	16.26	15.8	28.4	18.75	58.6	37.6
2	8.79	14.2	17.4	10.86	16.4	20.6	18.75	16.8	30.0	21.50	66.4	41.6
2 1/4	9.50	15.2	18.6	11.81	17.5	21.9	21.50	17.3	31.7	24.84	75.0	45.6
2 1/2	9.85	15.7	19.1	12.25	18.0	22.4	23.36	17.9	32.7	26.84	79.2	47.6
2 3/4	10.25	16.3	19.7	12.76	18.6	23.0	25.32	18.6	33.7	28.90	83.9	49.6
3	10.75	17.0	20.4	13.36	19.3	23.7	27.48	19.3	34.8	31.17	89.6	51.6
3 1/4	11.31	17.7	21.2	14.03	20.0	24.4	29.83	20.0	36.0	33.63	95.8	53.6
3 1/2	11.72	18.2	21.7	14.57	20.6	24.9	31.37	20.6	36.7	35.34	101.3	55.6
3 3/4	12.19	18.8	22.3	15.18	21.2	25.5	33.06	21.2	37.4	37.19	107.1	57.6
4	12.71	19.5	23.0	15.85	21.9	26.2	34.90	21.9	38.1	39.17	113.3	59.6
4 1/4	13.29	20.2	23.7	16.58	22.7	26.9	36.89	22.7	38.8	41.29	119.8	61.6
4 1/2	13.72	20.7	24.2	17.17	23.2	27.4	38.14	23.2	39.4	43.54	126.6	63.6
4 3/4	14.21	21.3	24.8	17.81	23.8	27.9	40.44	23.8	40.1	45.93	133.7	65.6
5	14.75	22.0	25.4	18.50	24.4	28.5	42.90	24.4	40.8	48.46	141.1	67.6
5 1/4	15.34	22.7	26.1	19.25	25.1	29.2	45.53	25.1	41.5	51.14	148.8	69.6
5 1/2	15.77	23.1	26.5	19.71	25.5	29.6	47.26	25.5	41.9	53.00	154.8	71.6
5 3/4	16.25	23.6	27.0	20.21	26.0	30.1	49.11	26.0	42.5	55.00	161.8	73.6
6	16.78	24.2	27.6	20.76	26.6	30.6	51.19	26.6	43.1	57.14	169.1	75.6
6 1/4	17.35	24.8	28.2	21.36	27.2	31.2	53.41	27.2	43.7	59.42	176.8	77.6
6 1/2	17.77	25.2	28.6	21.81	27.6	31.6	55.87	27.6	44.2	61.84	184.8	79.6
6 3/4	18.25	25.7	29.1	22.41	28.1	32.1	58.47	28.1	44.8	64.40	193.1	81.6
7	18.81	26.3	29.7	23.06	28.7	32.7	61.21	28.7	45.4	67.10	201.8	83.6
7 1/4	19.42	26.9	30.3	23.76	29.3	33.3	64.09	29.3	46.0	69.94	210.8	85.6
7 1/2	19.85	27.3	30.7	24.21	29.7	33.7	66.61	29.7	46.5	72.61	219.1	87.6
7 3/4	20.33	27.8	31.2	24.81	30.2	34.2	69.27	30.2	47.1	75.42	227.8	89.6
8	20.85	28.3	31.7	25.46	30.7	34.7	72.07	30.7	47.6	78.27	236.8	91.6
8 1/4	21.41	28.9	32.3	26.16	31.3	35.3	74.91	31.3	48.2	81.16	246.1	93.6
8 1/2	21.83	29.3	32.7	26.61	31.7	35.7	77.49	31.7	48.6	83.69	254.8	95.6
8 3/4	22.31	29.8	33.2	27.21	32.2	36.2	80.31	32.2	49.1	86.26	263.8	97.6
9	22.85	30.4	33.7	27.86	32.7	36.7	83.27	32.7	49.6	88.88	273.1	99.6
9 1/4	23.45	31.0	34.3	28.56	33.3	37.3	86.37	33.3	50.1	91.54	282.8	101.6
9 1/2	23.87	31.4	34.7	28.91	33.7	37.7	88.81	33.7	50.5	93.94	291.8	103.6
9 3/4	24.43	32.0	35.3	29.61	34.3	38.3	91.89	34.3	51.1	96.69	301.1	105.6
10	25.01	32.6	35.9	30.26	34.8	38.8	94.61	34.8	51.6	99.19	310.8	107.6
10 1/4	25.63	33.2	36.5	30.96	35.4	39.4	97.57	35.4	52.1	101.94	320.8	109.6
10 1/2	26.05	33.6	36.9	31.41	35.8	39.8	99.91	35.8	52.5	104.14	329.1	111.6
10 3/4	26.63	34.2	37.5	32.11	36.4	40.4	102.91	36.4	53.1	106.99	338.8	113.6
11	27.25	34.8	38.1	32.81	37.0	41.0	105.97	37.0	53.6	109.89	348.8	115.6
11 1/4	27.85	35.4	38.7	33.56	37.6	41.6	109.07	37.6	54.1	112.84	358.8	117.6
11 1/2	28.27	35.8	39.1	33.91	37.9	41.9	111.21	37.9	54.4	114.84	367.1	119.6
11 3/4	28.85	36.4	39.7	34.61	38.5	42.5	114.37	38.5	55.0	117.89	376.8	121.6
12	29.45	37.0	40.3	35.26	39.1	43.1	117.57	39.1	55.6	120.99	386.8	123.6
12 1/4	30.07	37.6	40.9	35.96	39.7	43.7	120.71	39.7	56.1	123.94	396.8	125.6
12 1/2	30.49	38.0	41.3	36.41	40.1	44.1	122.81	40.1	56.5	125.94	405.1	127.6
12 3/4	31.11	38.6	41.9	37.11	40.7	44.7	125.97	40.7	57.1	128.99	415.1	129.6
13	31.75	39.2	42.5	37.81	41.3	45.3	129.17	41.3	57.6	132.09	425.1	131.6
13 1/4	32.37	39.8	43.1	38.56	41.9	45.9	132.41	41.9	58.1	135.14	435.1	133.6
13 1/2	32.79	40.2	43.5	38.91	42.3	46.3	134.51	42.3	58.5	137.14	443.8	135.6
13 3/4	33.41	40.8	44.1	39.61	42.9	46.9	137.67	42.9	59.1	140.19	453.8	137.6
14	34.05	41.4	44.7	40.26	43.5	47.5	140.87	43.5	59.6	143.29	463.8	139.6
14 1/4	34.67	42.0	45.3	40.96	44.1	48.1	144.07	44.1	60.1	146.34	473.8	141.6
14 1/2	35.09	42.4	45.7	41.41	44.5	48.5	146.17	44.5	60.5	148.34	482.1	143.6
14 3/4	35.71	43.0	46.3	42.11	45.1	49.1	149.37	45.1	61.1	151.39	492.1	145.6
15	36.35	43.6	46.9	42.81	45.7	49.7	152.61	45.7	61.6	154.49	502.1	147.6
15 1/4	36.97	44.2	47.5	43.56	46.3	50.3	155.87	46.3	62.1	157.54	512.1	149.6
15 1/2	37.39	44.6	47.9	43.91	46.7	50.7	157.97	46.7	62.5	159.54	520.8	151.6
15 3/4	38.01	45.2	48.5	44.61	47.3	51.3	161.17	47.3	63.1	162.59	530.8	153.6
16	38.65	45.8	49.1	45.26	47.9	51.9	164.41	47.9	63.6	165.64	540.8	155.6
16 1/4	39.27	46.4	49.7	45.96	48.5	52.5	167.61	48.5	64.1	168.69	550.8	157.6
16 1/2	39.69	46.8	50.1	46.41	48.9	52.7	169.71	48.9	64.3	170.69	559.1	159.6
16 3/4	40.31	47.4	50.7	47.11	49.5	53.3	172.97	49.5	64.9	173.74	569.1	161.6
17	40.95	48.0	51.3	47.81	50.1	53.9	176.17	50.1	65.4	176.79	579.1	163.6
17 1/4	41.57	48.6	51.9	48.56	50.7	54.5	179.41	50.7	65.9	179.84	589.1	165.6
17 1/2	41.99	48.9	52.3	48.91	51.1	54.9	181.51	51.1	66.3	181.84	597.8	167.6
17 3/4	42.61	49.5	52.9	49.61	51.7	55.5	184.77	51.7	66.9	184.89	607.8	169.6
18	43.25	50.1	53.5	50.26	52.3	56.1	187.97	52.3	67.5	187.94	617.8	171.6
18 1/4	43.87	50.7	54.1	50.96	52.9	56.7	191.21	52.9	68.1	190.99	627.8	173.6
18 1/2	44.29	51.1	54.5	51.41	53.3	57.1	193.31	53.3	68.5	192.99	636.1	175.6
18 3/4	44.91	51.7	55.1	52.11	53.9	57.7	196.57	53.9	69.1	196.04	646.1	177.6
19	45.55	52.3	55.7	52.81	54.5	58.3	199.87	54.5	69.6	199.09	656.1	179.6
19 1/4	46.17	52.9	56.3	53.56	55.1	58.9	203.17	55.1	70.1	202.14	666.1	181.6
19 1/2	46.59	53.3	56.7	53.91	55.5	59.3	205.27	55.5	70.5	204.14	674.8	183.6
19 3/4	47.21	53.9	57.3	54.61	56.1	59.9	208.57	56.1	71.1	207.19	684.8	185.6
20	47.85	54.5	57.9	55.26	56.7	60.5	211.87	56.7	71.6	210.24	694.8	187.6
20 1/4	48.47	55.1	58.5	55.96	57.3	61.1	215.17	57.3	72.1	213.29	704.8	189.6
20 1/2	48.89	55.5	58.9	56.41	57.7	61.5	217.27	57.7	72.5	215.29	713.1	191.6
20 3/4	49.51	56.1	59.5	57.11	58.3	62.1	220.57	58.3	73.1	218.34	723.1	193.6
21	50.15	56.7	60.1	57.81	58.9	62.7	223.87	58.9	73.6	221.39	733.1	195.6
21 1/4	50.77	57.3	60.7	58.56	59.5	63.3	227.17	59.5	74.1	224.44	743.1	197.6
21 1/2	51.19	57.7	61.1	58.91	59.9	63.7	229.27	59.9	74.5	226.44	751.8	199.6
21 3/4	51.81	58.3	61.7	59.61	60.5	64.3	232.57	60.5	75.1	229.49	761.8	201.6
22	52.45	58.9	62.3	60.26	61.1	64.9	235.87	61.1	75.6	232.54	771.8	203.6
22 1/4	53.07	59.5	62.9	60.96	61.7	65.5	239.17	61.7	76.1	235.59	781.8	205.6</

wood, Mr. Laslett deduced that the maximum resistance to compression is exerted when the area in square inches is to the length in inches precisely as 4 is to 5, for equal seasoning and equal species. In this ratio, the maximum resistance to crushing square balks on end, would be exerted for a 16 feet.

Timber Piles.

TABLE 175.—ULTIMATE STRENGTH OF TIMBER
(Brereton and Stoney.)

Ratio of Length to Least Breadth.	Ultimate Weight that can be borne per Square Foot of Section.	Ratio of Length to Least Breadth.	Ultimate Weight that can be borne per Square Foot of Section.
	Tons.		Tons.
10	120	35	44
15	118	40	40
20	115	45	37
25	100	50	33
30	90		

Transverse Strength of Timber Beams, of Large Scantling, supported at the Ends, Loaded at the Middle.*

Fir	$W = \frac{1.78bd^2}{l}$
Red pine	$W = \frac{1.39bd^2}{l}$
Quebec yellow pine	$W = \frac{1.39bd^2}{l}$
Pitch pine	$W = \frac{2.12bd^2}{l}$
English oak	$W = \frac{1.64bd^2}{l}$
French oak	$W = \frac{2.24bd^2}{l}$

W = breaking weight in tons.

b = breadth in inches.

d = depth in inches.

l = span in inches.

* *Manual of Rules, Tables and Data*, page 166.

Cast-Iron.

d
d
d
d

imeters, in inch

strength of c

FOUGHT-IRON.

perimeters.

results of Mr.

for tensile st
calculated. His ap
with a clear
of the bars is

LENGTH OF B
study.)

Extensio Fract	Extensio Fract
19	25.2 ps
30	23.5
55	19.4
100	20.5
16	22.2 ps
25	24.8 ps
37	21.8
55	12.5
92	9.0

mens test
nt. of 8
85.2 ps

Cast-iron under tension or compression does not exhibit any well-defined elastic limit. Mr Hodgkinson tested 1-inch square bars of cast-iron, 10 feet long, under a load of 5 tons in tension, the bar extended $\frac{1}{4}$ th part of its length, under the same load in compression, the bar extended $\frac{1}{10}$ th part of its length. In round numbers, it may be taken that elastic extension and elastic compression are each approximately $\frac{1}{1000}$ th part of the length, under a stress of 5 tons per square inch, or $\frac{1}{2000}$ th part of the length per ton per square inch, which is more than twice the rate of elastic extension of iron or of steel.

Influence of high temperature.

Cast-iron of average quality loses strength when heated above 120° F., and it becomes insecure at the freezing-point. At a red heat, its normal strength is reduced one-third.

Malleable cast-iron.

Cast-iron is rendered malleable by the extraction of part of the constituent carbon, approximating it to wrought-iron. The tensile strength of annealed malleable cast-iron is equivalent to over 25 tons per square inch; and 10 tons load per square inch is borne without distortion.

Columns.

TABLE 176.—SAFE LOAD ON HOLLOW CAST-IRON COLUMNS WITH FLAT ENDS AND BASE PLATES, LENGTH 20 TO 30 DIAMETERS.

(Shields.)

Thickness.	Load per Square Foot of Sectional Area of Metal	
	Length 20 to 25 Diameters.	25 to 30 Diameters.
	Tons.	Tons.
$\frac{1}{4}$ and upwards	2	$1\frac{3}{4}$
$\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{1}{2}$
$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{3}$
$\frac{1}{2}$	$1\frac{1}{4}$	1

TABLE 177 WEIGHT AND SAFE LOAD OF CAST-IRON COLUMNS, NOT EXCEEDING 20 DIAMETERS IN LENGTH.

(Load, two tons per square inch of sectional area.)

MEAN EXTERNAL DIAMETER OF COLUMNS, IN INCHES.												
34	34			44			54			Safe Load Tons.	Weight per Lineal Foot, Lbs.	
	Area, Sq. Ins.	Weight per Lineal Foot, Lbs.	Safe Load Tons.	Area, Sq. Ins.	Weight per Lineal Foot, Lbs.	Safe Load Tons.	Area, Sq. Ins.	Weight per Lineal Foot, Lbs.	Safe Load Tons.			
1	7.07	22.2	141	7.85	24.7	15.7	10.99	31.6	22.0	12.57	39.6	27.1
1	6.28	19.8	126	8.81	27.8	17.7	12.76	40.2	25.5	14.73	46.1	29.5
1	5.49	17.8	112	9.81	31.1	19.8	14.14	44.5	28.3	16.49	51.9	33.0
1	4.70	15.8	99	10.80	34.0	21.6	14.14	44.5	28.3	16.49	51.9	33.0
1	3.91	13.8	86	11.80	36.9	23.4	14.14	44.5	28.3	16.49	51.9	33.0
1	3.12	11.8	74	12.80	39.8	25.2	14.14	44.5	28.3	16.49	51.9	33.0
1	2.33	9.8	63	13.80	42.7	27.0	14.14	44.5	28.3	16.49	51.9	33.0
1	1.54	7.8	53	14.80	45.6	28.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.75	5.8	44	15.80	48.5	30.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	3.8	36	16.80	51.4	32.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	1.8	28	17.80	54.3	34.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	20	18.80	57.2	36.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	12	19.80	60.1	37.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	4	20.80	63.0	39.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	21.80	65.8	41.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	22.80	68.7	43.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	23.80	71.6	45.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	24.80	74.5	46.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	25.80	77.4	48.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	26.80	80.3	50.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	27.80	83.2	52.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	28.80	86.1	54.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	29.80	89.0	55.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	30.80	91.9	57.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	31.80	94.8	59.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	32.80	97.7	61.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	33.80	100.6	63.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	34.80	103.5	64.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	35.80	106.4	66.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	36.80	109.3	68.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	37.80	112.2	70.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	38.80	115.1	72.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	39.80	118.0	73.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	40.80	120.9	75.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	41.80	123.8	77.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	42.80	126.7	79.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	43.80	129.6	81.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	44.80	132.5	82.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	45.80	135.4	84.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	46.80	138.3	86.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	47.80	141.2	88.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	48.80	144.1	90.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	49.80	147.0	91.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	50.80	150.0	93.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	51.80	152.9	95.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	52.80	155.8	97.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	53.80	158.7	99.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	54.80	161.6	100.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	55.80	164.5	102.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	56.80	167.4	104.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	57.80	170.3	106.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	58.80	173.2	108.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	59.80	176.1	109.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	60.80	179.0	111.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	61.80	181.9	113.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	62.80	184.8	115.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	63.80	187.7	117.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	64.80	190.6	118.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	65.80	193.5	120.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	66.80	196.4	122.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	67.80	199.3	124.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	68.80	202.2	126.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	69.80	205.1	127.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	70.80	208.0	129.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	71.80	210.9	131.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	72.80	213.8	133.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	73.80	216.7	135.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	74.80	219.6	136.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	75.80	222.5	138.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	76.80	225.4	140.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	77.80	228.3	142.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	78.80	231.2	144.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	79.80	234.1	145.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	80.80	237.0	147.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	81.80	240.0	149.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	82.80	242.9	151.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	83.80	245.8	153.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	84.80	248.7	154.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	85.80	251.6	156.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	86.80	254.5	158.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	87.80	257.4	160.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	88.80	260.3	162.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	89.80	263.2	163.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	90.80	266.1	165.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	91.80	269.0	167.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	92.80	271.9	169.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	93.80	274.8	171.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	94.80	277.7	172.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	95.80	280.6	174.6	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	96.80	283.5	176.4	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	97.80	286.4	178.2	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	98.80	289.3	180.0	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	99.80	292.2	181.8	14.14	44.5	28.3	16.49	51.9	33.0
1	0.00	0.0	0	100.80	295.1	183.6	14.14	44.5	28.3	16.49		

TABLE 177.—CAST-IRON COLUMNS (continued).

MEAN INTERNAL DIAMETER OF COLUMN, IN INCHES												
	6				7				8			
	Area, Sq. Ins.	Weight per Foot, Lbs.	Safe Load, Tons.	Area, Sq. Ins.	Weight per Foot, Lbs.	Safe Load, Tons.	Area, Sq. Ins.	Weight per Foot, Lbs.	Safe Load, Tons.	Area, Sq. Ins.	Weight per Foot, Lbs.	Safe Load, Tons.
10	28.27	89.0	36.5	81.42	99.3	62.8	84.56	108.9	69.1	87.70	118.7	73.4
11	31.36	108.2	68.7	88.29	120.6	76.6	42.21	133.0	84.4	46.14	111.8	92.3
12	40.06	126.2	80.1	44.77	141.0	89.5	49.48	155.9	99.0	54.19	170.7	108.4
13	45.36	142.9	90.7	50.85	160.2	101.7	56.35	177.2	112.7	61.85	194.8	123.7
14	50.27	158.3	100.5	56.55	178.1	113.1	62.83	197.9	125.7	69.11	217.7	138.2
15	54.78	172.5	109.6	61.87	194.8	128.7	68.92	217.1	137.8	76.99	239.4	152.0
16	58.90	185.5	117.8	66.76	210.3	133.5	74.51	234.7	149.0	82.17	259.8	164.9
17	62.64	197.8	125.3	71.27	224.5	142.5	79.91	251.7	159.8	88.56	278.9	177.1
18	65.97	207.8	131.9	75.40	237.5	150.8	84.72	266.3	169.4	94.25	296.9	188.5
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TABLE 177.—CAST-IRON COLUMNS (continued).

MEAN EXTERNAL DIAMETER OF COLUMN, IN INCHES.																								
15				16				17				18				19								
The thickness of Metal.	Inch.	Weight per Lin. ft. Foot.		Safe Load Tons.	Area, Sq. Ins.		Weight per Lin. ft. Foot.	Safe Load Tons.	Area, Sq. Ins.		Weight per Lin. ft. Foot.	Safe Load Tons.	Area, Sq. Ins.		Weight per Lin. ft. Foot.	Safe Load Tons.								
		Lbs.	Foot.		Lbs.	Foot.			Lbs.	Foot.			Lbs.	Foot.			Lbs.	Foot.						
1	1 1/4	63.66	900.4	127.2	68.33	215.2	136.7	73.04	230.1	146.1	77.75	245.9	151.5	82.47	259.8	164.9								
1 1/4	1 1/2	73.03	930.0	146.1	78.34	246.7	156.7	83.84	264.1	167.7	89.34	281.4	173.7	94.84	298.7	189.7								
1 1/2	2	81.68	957.3	162.4	87.06	277.1	175.9	94.2	296.9	188.5	100.63	316.7	201.1	105.81	336.4	213.6								
2	2 1/4	96.12	983.3	194.4	97.10	306.1	194.4	104.26	328.4	208.5	111.33	350.7	222.7	118.40	373.0	236.8								
2 1/4	2 1/2	98.17	998.2	196.3	106.03	334.0	212.1	113.88	358.7	227.8	121.74	383.18	243.5	129.61	408.4	259.2								
2 1/2	2 3/4	107.83	923.4	211.7	114.47	360.6	228.6	123.11	387.8	246.2	131.75	415.31	263.5	140.40	442.3	280.8								
3	3	113.10	956.3	226.2	122.72	385.9	246.0	131.95	417.6	263.9	141.37	445.3	282.7	150.80	475.0	301.6								
													22				23				24			
1	1 1/4	54.6	188.0	119.3	62.88	197.9	125.7	65.37	207.8	131.9	69.11	217.7	139.2	72.26	227.6	144.5								
1 1/4	1 1/2	73.03	231.9	147.3	77.56	244.3	155.1	81.18	256.6	162.9	85.41	269.0	170.8	89.34	281.1	178.7								
1 1/2	2	87.14	244.6	171.4	91.89	289.4	188.8	96.51	304.3	193.2	101.31	319.1	200.6	106.03	334.0	212.1								
2	2 1/4	97.14	311.5	230.7	105.83	323.4	211.7	111.34	350.7	227.7	116.89	368.0	233.7	122.32	385.3	244.9								
2 1/4	2 1/2	107.83	356.2	226.2	119.38	376.0	238.7	125.99	395.8	251.3	131.94	415.6	258.9	138.23	435.4	270.5								
2 1/2	2 3/4	113.10	395.2	251.9	132.54	417.5	265.1	139.07	439.7	279.2	146.67	462.0	293.3	153.74	494.3	307.5								
3	3	123.42	432.9	274.9	145.30	457.7	290.6	153.15	482.4	305.3	161.01	507.9	322.0	168.86	531.9	337.7								
3 1/4	3 1/2	131.4	464.4	298.1	157.37	496.7	315.8	166.30	523.8	332.6	174.97	551.1	349.9	183.59	578.3	367.1								
3 1/2	4	131.4	504.7	320.4	169.63	534.4	339.3	179.07	564.1	358.1	188.50	593.8	377.0	197.92	623.4	395.8								

Transverse Strength of Cast-Iron.

The strength of beams of cast-iron varies very much according to the scantling. The breaking weights of 1-inch square bars of cast-iron supported at the ends, loaded at the middle, as tested by Mr. Barlow, and subsequently by Mr. Robert Stephenson, was expressed by the formula (65)

$$W = \frac{bd^2}{l} \times 13.6 \quad . \quad . \quad . \quad (65)$$

in which W is the breaking weight in tons, and b , d , and l , are the breadth, depth, and length of span in inches. With 1 for a coefficient, the formula shows that the breaking weight of a 1-inch square bar, at 12 inches of span, is just one ton; and if the span be expressed in feet the formula (65) becomes

$$W = \frac{bd^2}{l} \quad . \quad . \quad . \quad (66)$$

in which b and d are in inches, and l in feet.

For the reason given, no constant coefficient can be employed with accuracy. The subjoined formulae (67) and (68) give results which may safely be taken; for a minimum factor of 7 tons tensile strength per square inch, with a wide margin of excess.

Ultimate strength of rectangular bars of ordinary cast-iron, freely supported, loaded at the middle.

$$W = \frac{8bd^2}{l} \quad . \quad . \quad . \quad (67)$$

Ultimate strength of round bars of cast-iron.

$$W = \frac{5d^3}{l} \quad . \quad . \quad . \quad (68)$$

W , load in tons; b , d , and l in inches.

Deflection of cast-iron rectangular bars of uniform section loaded at the middle.

$$D = \frac{Wl^3}{28000bd^3} \quad . \quad . \quad . \quad (69)$$

D the deflection, and b , d , and l the breadth, depth, and span: all in inches

Torsional Strength of Cast-Iron.

Solid round shaft	WR	$1.372d^3$	(70)
Hollow round shaft	WR	$1.372(d^3 - d'^3)$	(71)
Square shaft	WR	$1.967b^3$	(72)

W = force applied, in tons.

R = radius of force, in inches.

d and d' = external and internal diameters, in inches.

b = side of square, in inches.

These formulas are based on a tensile strength of cast-iron equal to 7 tons per square inch.

STRENGTH OF WROUGHT-IRON.*Mr. D. Kirkaldy's early experiments.*

From the original and extensive results of Mr. David Kirkaldy's test-trials of bars and plates for tensile strength, the following summary results are obtained. His specimens were formed with a head at each end, with a clear length of 7 inches. The elongation or extension of the bars is added.

TABLE 178.—ULTIMATE TENSILE STRENGTH OF ROUND BAR IRON. (Mr. Kirkaldy)

Bars.	Tons per Square Inch.	Extension before Fracture.
Yorkshire rolled bars	27.89	25.2 per cent.
Staffordshire "	25.90	23.5 "
Lanarkshire "	26.55	19.4 "
Rivet Iron	26.90	20.5 "
Average	26.45	22.2 per cent.
Hammered scrap, forged down	23.85	24.8 per cent.
Crank shaft, scrap iron, with fibre	20.37	21.8 "
" " across fibre	18.77	12.5 "
Armour plate, across fibre	16.92	9.0 "

The contracted sectional area of specimens tested to fracture, varied considerably, from 29.5 per cent. of the original area for Swedish charcoal iron bars to 85.2 per cent. for common Scotch iron bars. Thus—

Iron.	Tensile Strength	Contracted Sectional Area.
Swedish charcoal	20.8	per cent.
Staffordshire charcoal	33.4	"
Yorkshire, Lowmoor	45.3	"
Staffordshire, B. B. Scrap	17.8	"
" S. O. Crown	33.4	"
Scotch, extra best best	58.5	"
" best best	68.9	"
" common	71.5	"
" common	65.2	"

The strength as the diameter was reduced by rolling down from $1\frac{1}{4}$ to $\frac{1}{2}$ inch, and intermediate sizes, was increased 19 per cent., or from 22.38 tons to 26.65 tons per square inch; whilst the extension was reduced from 28.3 per cent. to 23.8 per cent.

The strength of $1\frac{1}{4}$ inch rolled bars, turned down to 1 inch in diameter, was increased 5 per cent.; and the extension was augmented from 17.2 per cent. to 19.3 per cent.

Four $1\frac{1}{4}$ inch round bars, reduced by forging to 1 inch and $\frac{1}{2}$ inch in diameter, showed an increase of 4 per cent. of strength; and the extension was reduced from 24.5 per cent. to 17.3 per cent.

Five different 1 inch bars, when reheated for repair, showed 3.8 per cent. less tensile strength; and the extension was increased from 10.1 per cent. to 32.6 per cent.

Two pieces of a $\frac{1}{2}$ inch bar of iron were tested:—one in the ordinary condition; the other after having been heated to a welding heat, and cooled slowly. The strength was not materially affected, and the extension was reduced from 22.9 per cent. to 17.7 per cent.

To test the influence of intense cold, three pieces of a $\frac{1}{2}$ inch bar were tested: one at 64° F., the others at 23° F. The colder bars broke with 2.4 per cent. less load; and with an extension of 23 per cent., against 24.9 per cent. at 64° F.

To test the effect of notching a bar, several 1 inch round bars of different makes were notched or grooved to a diameter of .7 inch, and broken at the notch; then turned down in the body to the same diameter, and broken through the body. The average tensile strengths per square inch, and the corresponding contracted sectional areas, were as follows:—

	Tensile Strength per Square Inch.	Contracted Sectional Area.
Notched	32.91 tons	85 per cent.
Turned down	27.61 "	58.4 "
Rough bar	26.04 "	39.9 "

Showing a remarkable excess of resistance at the notch relatively to the sectional area, and a relatively large contracted area.

The influence of screwing bolts of $1\frac{1}{4}$ inch, 1 inch, and $\frac{3}{4}$ inch in diameter, on the tensile strength, showed 25 per cent average reduction of tensile strength per square inch. Chased screws were weaker than screws made with dies, whilst screws cut with blunt dies were less weakened than those cut with new and sharp dies.

The influence of ordinary welded joints in several irons, showed an average of 19.4 per cent reduction of tensile strength, varying from 2.6 per cent, to 43.8 per cent.

The effect of the sudden application of tensile stress to 1 inch round bars of iron, with or without a jerk, as against the gradual application of stress, was to reduce the load necessary to cause fracture by 13.6 per cent, with an extension of 20.1 per cent as against 24.6 per cent with the gradual application of the stress.

Three pieces of iron cut out of a large crank shaft, were forged down and turned to 1 inch in diameter. Tested against two other pieces cut out, and simply turned to 1 inch in diameter, they showed 20 per cent. greater strength, but reduced extension.

The influence of the removal of the skin on strength of hammered iron, was shown by two $1\frac{1}{4}$ inch square bars turned down to 1 inch in diameter, the tensile strength being $5\frac{1}{2}$ per cent. more than that of 1-inch square hammered bars in their skins, with a greater degree of extension.

A $1\frac{1}{4}$ -inch round bar of Bowling iron was cut into several pieces, which were turned, forged down and hardened, with the following results:-

Diameter		Tons per Sq. In.	Extension.
Turned to 1 inch		27.15	28.3 per cent.
Forged to .87	hardened in water	32.79	19.6 "
" " .78	" oil	28.85	19.8 "
" " .70	" tar	28.06	22.4 "

The second of these tensile strengths, 32.79 tons per square inch, was the maximum tensile strength of iron observed by Mr. Kirkaldy.

By case-hardening and cooling in water, or in oil, or slowly, an average of 8.4 per cent. reduction of tensile strength was effected, with only one-fourth of the extension.

In cold-rolling $\frac{3}{4}$ -inch bars, the tensile strength was increased 18 per cent., and the elongation reduced to one-fifth. By subsequent annealing, the gain of strength disappeared.

Angle-iron, ship-strap, and beam-iron are less in tensile strength by from 1 ton to 2 tons per square inch than bar iron; and the extensions also are less.

Mr. Kirkaldy found that the density of iron was diminished by cold-rolling:—

	Ordinary.	Cold Rolled.	Reduced.
Bar iron, specific gravity .	7.636	7.582	7 per cent.
Boiler plate "	7.566	7.539	37. "

The specific gravity of iron was also reduced by stretching under tensile stress:—

	Specific Gravity.	
	Before stretching.	After stretching.
Three 1-inch Yorkshire iron bars, stretched to .90 inch diameter. }	7.752	7.674
Two .83-inch Blochairn bars, stretched to .76-inch diameter. }	7.636	7.569
Average for five bars	7.760	7.632

Showing an average of .128 reduction of specific gravity, or 1.65 per cent.

Swedish Hammered Bar Iron.

Mr. Kirkaldy tested round bars, 3 inches, 2 inches, 1 inch, and $\frac{1}{2}$ inch in diameter, with flat bars $\frac{1}{2}$ inch thick, by 3 inches, 2 inches, and $1\frac{1}{2}$ inches wide, for tensile strength. The round specimens had 10 inches of clear length, and the flat specimens 15 inches.

The average ultimate strength of the round bars was 20.13 tons per square inch, with an extension of 24.6 per cent.; and that of the flat bars was 21.4 tons, with an extension of 16.7 per cent. $1\frac{1}{2}$ inch turned specimens had an elastic strength of 11.05 tons, about 60 per cent. of the ultimate strength, 18.80 tons.

Under compressive stress three $1\frac{1}{2}$ inch round specimens, respectively $1\frac{1}{2}$, 3, and 15 inches high, were crushed under a stress of 66.45, 37.90, and 12.53 tons per square inch.

A 1-inch cube failed under a load of 82.20 tons.

French Bar Iron.

The strength of French bar iron of various denominations is given in Table 179.

TABLE 179. FRENCH BAR IRON—TENSILE STRENGTH
(Debaucq.)

Description	Ultimate Strength in Tons per Square Inch	Exten- sion
	Tons.	Per cent.
Creusot, No. 1, Rails	26.03	10
" No. 2, Merchant Iron . . .	24.00	15
" No. 3, Horse-shoe Iron . . .	24.13	18
" No. 4, Bolts and Rivets . . .	24.45	21
" No. 5, Boiler Plates	24.51	25
" No. 6, Machinery Iron . . .	24.57	20
" No. 7, Exceptional	24.89	34
Chantillon and Commeny, No. 1, Axles	22.86	25
" " No. 5	26.35	13
Terre-Noire, La Voûte, and Besseges		
Ordinary	18.42	17
Strong	20.96	20
Superior	21.59	25
Fine	23.50	26
Saint Etienne, granular, No. 1 . .	17.78	...
" " No. 7	22.86	12
" fibrous No. 1	16.51	2
" " No. 7	22.86	18
Porte Eveque (Isere), No. 1 . . .	23.50 to 27.0	...
" " No. 7	21.59	18
Lyons Railway Company:		
No. 1, fine charcoal	24.13	25
No. 2, strong superior	23.50	23
No. 3, strong	22.28	18
No. 4, ordinary	20.96	12

In general, good ordinary French wrought-iron takes a tensile breaking weight of from 22 tons to 24 tons per square inch. The limit of elasticity corresponds to $6\frac{1}{2}$ tons per square inch, whilst the maximum stress allowed in construction is 6 kilogrammes per square millimetre, or 3.81 tons per square inch, about $\frac{1}{4}$ th of the ultimate strength. In compression, the elastic limit is for fine grain iron 3.81 tons, and for fibrous iron, 9 tons; with ultimate rupturing stresses of 63 tons and 51 tons respectively.

Mr. Kirkaldy's Experiments with Iron Plates.

The tensile strength of iron plates, from $\frac{3}{4}$ inch thick, in specimens $1\frac{1}{2}$ inches and 2 inches wide, is given in Table 180.

TABLE 180. **APPROXIMATE TENSILE STRENGTH OF IRON PLATES.**

(By Kirkaldy.)

Plates.	Tons per Square Inch		Extension	
	With Fibre.	Across Fibre	With Fibre	Across Fibre
	Tons	Tons	Per cent.	Per cent.
Yorkshire	24.55	22.64	13.1	14.5
Staffordshire	23.01	21.40	9.3	10.2
Durham	22.89	21.39	9.5	10.5
Shropshire	23.37	19.22	9.6	10.5
Lanarkshire	21.96	19.56	7.0	10.5
Averages	23.20	20.84	9.8	11.0

The tensile strength across the fibre is from $1\frac{1}{2}$ to $2\frac{1}{2}$ tons per square inch less than that with the fibre. The difference is 10 per cent.

Fractured Sectional Area of Iron Plates

	With Fibre	Across Fibre
Yorkshire	63.5 per cent.	79.7 per cent. of original
"	76.5 "	83.7 "
Staffordshire	78.5 "	89.9 "
S. C. Crown		
Staffordshire	84.8 "	92.0 "
Bradley		
Scotch best boiler	87.8 "	93.3 "
Staffordshire best best	90.9 "	94.6 "
Scotch Ship	95.4 "	97.5 "
Scotch common	94.4 "	98.5 "
Averages	84.0	91.0

By cold-rolling, pieces of Biocharon plate $\frac{3}{4}$ inch thick reduced to two-thirds of their thickness, were nearly doubled in length, but the extension was annulated. By annealing after cold-rolling, only $2\frac{1}{2}$ tons of the gain of strength remained, and the extension was doubled.

Krupp Iron Plates.

Mr. Kirkaldy tested a number of Krupp iron plates, and, for comparison, Lowmoor plates, $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, and $\frac{3}{4}$ inch thick, for which testing specimens 2 inches wide, 10 inches long for extension were prepared. The specimens were tested lengthwise, crosswise, annealed and unannealed. The following results were as follows.

	Krupp.	Yorkshire.
Elastic strength per square inch	11.2 tons	12.2 tons
Ultimate " "	21.5 "	20.2 "
Ratio of elastic to ultimate strength	52.1 per cent.	60.4 per cent.
Extension at 30,000 pounds per square inch	1.94 "	.85 "
Ultimate extension	22.6 "	14.8 "
Ratio of area of fracture	66.2 "	81.4 "

The elastic strength of the annealed specimens was from 10 to 60 tons less than that of the unannealed specimens.

TABLE 181. ULTIMATE TENSILE STRENGTH OF GALVANIZED IRON SHEETS.

Thickness.	Extension in 10 inches.	Resistance per Square In. h.
	Per cent.	Tons.
B. W. G. No. 25, with fibre	9	27.4
" " across fibre	7.4	21.8
" No. 23, with fibre	8.5	26.2
" " across fibre	6.3	22.1
" No. 21, with fibre	9.9	24.6
" " across fibre	11.2	21.0

French Plate Iron and Sheet Iron.

Iron plates and sheets are generally disposed in six classes as example:—

		Tensile Strength per Square Inch	Extension
Creusot.			
No. 2		21.08 tons	6 per cent.
" 3		21.40 "	10 "
" 4		22.03 "	14 "
" 5		22.10 "	18 "
" 6		22.61 "	22 "
" 7		23.30 "	26 "
Denain and Anzin.			
No. 2		19.05 tons	3 per cent.
" 3 Boilers		19.05 "	5 "
" 4. Common for the Marine		20.96 "	8 "
" 5. Ordinary	" "	22.22 "	12 "
" 6. Superior	" "	22.86 "	18 "
" 7. Fine	" "	23.50 "	20 "

In general, the resistance of the plates for the market across the grain is from $2\frac{1}{2}$ tons to $3\frac{1}{4}$ tons less than with the grain.

Influence of Temperature on the Tensile Strength of Wrought-Iron.

According to the results of Sir Wm Fairbairn's experiments, the strength of ordinary Staffordshire plates, either with or across the grain, remained the same for temperatures varying from 0° F. to 400° F. This higher temperature is that of steam of 235 lbs. effective pressure per square inch. At higher temperatures, the strength declined and at a red heat, it fell from an average of 20 tons to $15\frac{1}{4}$ tons per square inch.

TABLE 182. DECREASE IN TENSILE STRENGTH OF WROUGHT-IRON, WITH RISE OF TEMPERATURE.

(Kollman.)

Temperature.			Temperature.		
Decrease in Strength			Decrease in Strength		
Centigrade.	Fahrenheit.	Per cent.	Centigrade.	Fahrenheit.	Per cent.
0	32	100	600	1112	81
200	392	7	700	1292	84
300	572	10	800	1472	89
400	752	27	1000	1832	96
500	932	62			

M. Debaume states that the statical resistance is not affected by cold; but that the resistance to shocks is diminished by it. For temperatures from 0° C. to 100° C., or 32° F. to 212° F., there is no change; at 200° C., or 392° F., the tensile resistance is reduced 5 per cent.; at 300° C., or 572° F., reduced 10 per cent.; at 500° C., or 932° F., 60 per cent.; at 700° C., or 1292° F., 80 per cent.; at 900° C., or 1,652° F., 90 per cent.; at 1,000° C., or 1,832° F., the reduction of strength amounts to 95 per cent., leaving 5 per cent. of resisting strength. These results have been obtained for fibrous iron, fine grain iron, and Bessemer steel.

Working Temperatures.

The leading temperatures at which iron is worked are these :—

Brown-Red Heat, about 700° C., or 1,300 F. : the lower limit for working iron.

Cherry-Red Heat, about 950° C., or 1,730° F. : iron can be dressed, or rectified.

Red-White Heat, about 1,300° C., or 2,370° F. ; iron easily worked.

Welding Heat, about 1,500° C., or 2,730° F.

Experiments of the Steel Committee of Civil Engineers, with Bar Iron.

1½ inch round bars of Lowmoor iron, and S. C. Crown, Staffordshire iron, were tested for tensional strength and compressive strength, to the elastic limit, as well as for ultimate tensile strength. The bars were in lengths of 10 feet, for tension and for compression.

The summary average results of the tests are given in Table 183 (p. 355).

Transverse Strength of Wrought-Iron.

The general formula (3), page 322, as follows :—

$$W = 1.167bd^2s \quad (73)$$

gives the transverse strength of wrought-iron beams, supported at both ends and loaded at the middle, by substituting for *s* the ultimate tensile strength of the metal. Taking *s* = tons per square inch.

Transverse Strength of Wrought-Iron Beams or Bars supported at both ends, loaded at the middle.

$$\text{Square or Rectangular } W = \frac{23.3bd^2}{l} \quad . \quad . \quad . \quad (74)$$

$$\text{Round } . \quad . \quad . \quad W = \frac{14.6d^3}{l} \quad . \quad . \quad . \quad (75)$$

W = load at middle, in tons.

b = breadth of beam, in inches.

d = depth or diameter, in inches.

l = span, in inches.

For wrought-iron beams of other tensile strength, the co-efficients to be employed in equations (74) and (75), are as follows :—

Tensile Strength.	Coefficient for Equation (74).	For Equation (75)
21 tons	24.5	15.3
22 "	25.7	16.0
23 "	26.8	16.8
24 "	28.0	17.5
25 "	29.2	18.2

Elastic Transverse Strength of Wrought-Iron.

$$\text{Rectangular section } . \quad . \quad D = \frac{Wl^3}{47,000bd^3} \quad . \quad . \quad (76)$$

$$\text{Round section } . \quad . \quad D = \frac{Wl^3}{32,000d^4} \quad . \quad . \quad (77)$$

D = deflection in inches.

W = load at middle, in tons.

b = breadth in inches.

d = depth or diameter, in inches.

l = span in inches.

Torsional Strength of Wrought-Iron Bars or Shafts.

Taking the ultimate tensile strength of wrought-iron bars and shafts at 22½ tons per square inch, on an average, the formula for the torsional strength of wrought iron (p. 356) :—

TABLE 183.—STRENGTH OF ROUND WROUGHT-IRON BARS, $1\frac{1}{4}$ INCHES DIAMETER, 10 FEET LONG.
(The Steel Committee.)

I. TENSILE STRENGTH (Summary Averages).

Description of Iron.	Elastic Strength in Tons per Square Inch.	Elastic Extension in parts of the Length.		Breaking Weight in Tons per Square Inch.	Permanent Extension.	Ratio of Elastic to Breaking Strength.	Sectional Area of Fracture.
		Total.					
		Per cent.	Length = 1.				
Yorkshire	13.0	103, or 1 in 974	0.00079, or $\frac{1}{1265}$	25.8	12.5	50.6	64.6
S. C. Crown, Staffordshire	11.8	106, or 1 in 1046	0.00081, or $\frac{1}{1233}$	22.6	17.5	52.2	52.3
Mean	12.4	100, or 1 in 1000	0.00080, or $\frac{1}{1250}$	24.2	15.0	51.4	58.4

II. COMPRESSIVE STRENGTH (Summary Averages).

	Elastic Compression				
Yorkshire	12.6	0.97, or 1 in 1030	0.00077, or $\frac{1}{1300}$	...	...
S. C. Crown, Staffordshire	11.7	0.97, or 1 in 1030	0.00083, or $\frac{1}{1204}$	...	...
Mean	12.1	0.97, or 1 in 1030	0.00080, or $\frac{1}{1250}$	...	...

Ultimate Torsional Strength of Wrought-Iron Bars or Shafts.

Round bar or shaft	WR	$= 4.41d^3$	(7)
"	"	" $d = .283\sqrt{WH}$	(7)
Square	"	WR $= 6.32b^3$	(8)
"	"	" $b = .251\sqrt[3]{WH}$	(8)

The elastic torsional strength is about 40 per cent. of the ultimate torsional strength.

Torsional deflection of wrought-iron bars and shafts within the elastic limit, is given by the formula:—

Elastic Torsional Deflection of Wrought-Iron Bars and Shafts.

$$D = \frac{WRl}{1072d^4} \quad (9)$$

W = force in tons

R = radius of force, in inches.

WR = moment of force, in statical inch-tons.

d = diameter of round shaft, in inches.

b = side of square shaft, in inches.

l = length of shaft subject to torsional action, in inches.

D = total angular deflection in parts of one revolution.

STRENGTH OF STEEL.

The qualities of iron and steel depend principally on the proportion of constituent carbon, thus:—

	Percentage of Carbon
Ordinary iron	0 to 0.1
Either soft or mild steel	0.15 to 0.4
Granular iron	0.45 to 0.6
Soft or mild steel	0.65 to 1.0
Steely iron or puddled steel	1.05 to 1.5
Semi-mild steel	1.55 to 2.0
Cemented steel	2.05 to 2.5
Hard steel	2.55 to 3.0
Cast-iron	3.05 to 3.5

Mr Kirkaldy's Experiments.

Steel bars of from $\frac{1}{2}$ inch to 1 inch in diameter were tested and proved to from an average of 59 tons per square inch for tool steel, to an average of 29 tons for puddled steel.

greatest observed ultimate strength was 66·2 tons per square inch for tool-steel. The general results are given in Table 184.

TABLE 184. BAR STEEL · TENSILE STRENGTH.
(Mr. Kirkaldy—Summary.)

Name.	Treat- ment.	Size.	Breaking Weight per Sq. Inch (average).		Exten- sion.
			Inch.	Tons.	
Tool steel . . .	Forged	·53 to ·59		59·21	5·3
Chisel steel . . .	"	·56 to ·60		55·75	7·1
Shear steel . . .	"	·56 and ·57		52·87	13·5
Drift steel . . .	"	·57		51·76	13·3
Bessemer tool steel	"	·65 to ·75		49·75	5·5
Rivet steel . . .	Rolled	·75		47·75	10·5
Blister steel . . .	Forged	·57 to ·60		46·56	9·7
Steel for taps . . .	"	·57 and ·59		45·15	10·8
Krapp's bolt steel.	Rolled	·91 to ·93		41·08	15·3
Homogeneous metal . . .	"	·56		40·47	13·7
" " . . .	Forged	75		40·05	11·9
Spring steel . . .	"	·55 to ·57		32·37	18·0
Puddled steel . . .	Rolled	·75 to 1		31·32	11·3
" " . . .	Forged	·75 and 77		29·40	13·4

Experiments of the Steel Committee with Bar Steel.*

In the second series of experiments made at Woolwich Dockyard the object was to make experiments on the tension of long steel bars and iron bars, measuring the changes of length directly from the bars. For this purpose 91 round bars of steel and iron, each 14 feet long, $1\frac{1}{4}$ inches in diameter, were procured, consisting of 33 bars of crucible steel, 34 bars of Bessemer steel, 12 bars of Lowmoor iron, 6 bars of best Yorkshire iron, and 6 bars of usgat S. C. Crown, or Staffordshire iron. The extensions were measured on 10 feet length of each bar, and for compressive tests the bars were cut to a length of 12 feet, and the measurements made on a length of 10 feet. The bars were tested in their natural skins. They were thoroughly examined, straightened, and gauged before being

* For a detailed notice of these important experiments, see *Minutes of the Committee, Rules, Tables, and Data*, pages 570-596.

TABLE 18A.—STRENGTH OF STEEL BARS $\frac{1}{4}$ INCHES IN DIAMETER, 10 FEET LONG.

(The Steel Committee.)

I. TENSILE STRENGTH (SUMMARY AVERAGES.)

Description of Steel.	Elastic Strength in Tons per Square Inch.	Elastic Extension, in parts of the Length.			Breaking Weight in Tons per Square Inch.	Perma- nent Exten- sion.	Ratio of Elastic to Breaking Stress.	Sec- tional Area of Fracture.
		Total						
		Per cent.	length = 1						Per cent
Crucible.	Tons.	182, or 1 in 550	000078, or $\frac{1}{1275}$		Tons	5.1	58.0	90.0
		144, or 1 in 695	000078, or $\frac{1}{1275}$		34.22	12.0	53.8	62.5
Mean	20.9	163, or 1 in 613	000078, or $\frac{1}{1275}$		37.55	8.5	55.9	76.6

II. COMPRESSIVE STRENGTH (SUMMARY AVERAGES.)

		Elastic Compression.						
Crucible.	Bessemer.	23.3	175, or 1 in 570	000076, or $\frac{1}{1320}$	...	...	...	...
		17.8	137, or 1 in 782	000077, or $\frac{1}{1320}$	...	...	...	...
Mean		20.5	176, or 1 in 611	000076, or $\frac{1}{1320}$	...	...	...	...
	Bars tested for Compression, but not for Tension.							
Crucible tyres.	Bessemer: tyres.	23.0	172, or 1 in 581	000073, or $\frac{1}{1370}$	...	...	...	...
		24.0	182, or 1 in 550	000074, or $\frac{1}{1320}$	...	...	...	...

tested. The summary results have been given for bar iron, page 349, and those for the steel bars in Table 185, preceding.

The average compositions of the foregoing steels and the Yorkshire iron tested at the same time were as follows:—

	Crucible Steel. Per cent.	Bessemer Steel. Per cent.	Yorkshire Iron. Per cent.
Iron	98.89	99.20	99.49
Carbon . . . . .	.62	.33	.23
Silicon . . . . .	.114	.022	.10
Manganese . . . . .	.34	.39	.08
Sulphur . . . . .	.01	.035	.02
Phosphorus . . . . .	.026	.02	.08
	100.000	99.997	100.00
Specific gravity	7.842	7.855	7.758

Hadfield's Manganese Steel.

Though steel becomes brittle when the constituent manganese exceeds 2.75 per cent., yet it has been proved by Mr. R. A. Hadfield that when there is a proportion of not less than 7 per cent. of manganese, up to about 20 per cent., the product is a new metal, of superior strength. The Table 186 gives comparative tensile strengths and extensions of Siemens and Bessemer steels, including manganese steel of the following composition:—iron, 98.00, carbon, .85, silicon, .23, sulphur, .08, phosphorus, .09, and manganese, 13.75 per cent.

TABLE 186 —MANGANESE STEEL AND OTHER MILD STEELS.

Description	Breaking Loads	Extension
	Tons.	Per cent.
Siemens	26.16 to 28.51	31.25 to 35.49
Siemens	26.26 „ 28.21	32.78 „ 37.50
Bessemer	20.21 „ 28.44	31 „ 35
Siemens	23.10 „ 27.21	31 „ 34
Basic Bessemer	22.20 „ 25.80	30 „ 34
Siemens	26.54 „ 28.29	28 „ 31
Manganese steel	57 „ 65	39.8 „ 50.7

TABLE 187. COMPRESSED STEEL: TENSILE STRENGTH.
(W. H. Greenwood.)

Description.	Elastic limit, per Sq. inch	Ultimate Strength per Sq. inch	Contraction of Area at Fracture	Extension of 1 ft. of 1 in. dia.
I. <i>Test pieces cut longitudinally.</i>	Tons.	Tons.	Per cent.	Per cent.
Unpressed ingot.	11.11	23.18	4.41	8.76
Pressed ingot.	14.46	29.53	7.90	12.51
II. <i>Test pieces cut transversely.</i>				
Unpressed ingot.	11.43	28.04	3.61	7.91
Pressed ingot.	12.38	30.07	7.57	13.74

Whitworth Compressed Steel.

Steel subjected by the Whitworth process to compression while fluid, under a pressure of from 4 tons to 12 tons per square inch, gains in solidity and strength. In one instance the specific gravity of sound malleable steel containing 0.54 per cent. of carbon, was increased by compression from 7.8542 to 7.8795. The density of steel as a whole is increased by from 8 per cent. to 12 per cent. by compression pressure. Two sample ingots, pressed and unpressed, contained respectively 0.5 per cent. and 0.39 per cent. of carbon, and 0.35 per cent. and 0.4 per cent. of manganese. The results of tests for tensile strength are given in Table 187, the data of which are given by Mr. W. H. Greenwood. There is practically very little difference in the strengths of pieces cut longitudinally and transversely. But there is a considerable augmentation of elastic strength by compression.

Strength of Steel Plates.

Mr. Kirkaldy tested a number of steel plates for tensile strength, the results of which are summarised in Table 188. The plates were from $\frac{3}{16}$ inch to $\frac{1}{2}$ inch thick; and it is shown that whilst the puddled steels possessed about 10 per cent. less ultimate strength across the fibre than with it, the cast steel plates were at least as strong crosswise as lengthwise.

Landore steel plates tested by Mr. Kirkaldy were shown to have the same resisting strength lengthwise and crosswise as in the following Table 188. It is shown that the annealed samples have about $7\frac{1}{2}$ per cent. less tensile resistance than unannealed samples.

TABLE 188. LANDORE STEEL PLATES TENSILE STRENGTH.

	Tensile strength per Square Inch.			
	With the Grain.		Across the Grain.	
	Annealed.	Un-annealed.	Annealed.	Un-annealed.
Elastic strength, tons	12.8	14.5	12.8	14.4
Ultimate strength, "	28.8	31.1	28.8	31.2
Contraction of area at fracture, p cent.	43.2	41.1	44.9	40.5
Extension "	24.6	29.4	23.6	28.5

TABLE 189.—STEEL PLATES: TENSILE STRENGTH.
(Mr. Kirkaldy—Summary.)

Description of Steel	Thickness of Plate.	Breaking Weight per Square Inch		Extension in parts of the length.	
		With Fibre.	Across Fibre.	With Fibre.	Across Fibre.
	Inch	Tons.	Tons	Per cent.	Per cent.
Cast steel.	$\frac{3}{16}$ to $\frac{1}{2}$	38.82	39.90	12.90	13.96
Puddled steel.	$\frac{1}{8}$ to $\frac{5}{16}$	41.56	35.34	5.12	2.82
Mild puddled steel.	$\frac{1}{4}$ to $\frac{3}{8}$	33.16	30.22	4.90	5.70
Hard puddled steel.	$\frac{1}{4}$	45.80	38.11	4.90	3.30
Total averages	$\frac{3}{16}$ to $\frac{1}{2}$	39.83	35.90	6.95	6.44

The following results of tests of hematite steel and Krupp steel are given as examples comprising ultimate compressive strength:

	Hematite.	Krupp.
Elastic tensile strength, per square inch.	18.63 tons	19.10 tons
Ultimate tensile strength, per square inch.	32.27 "	42.07 "
Extension.	19.2 per cent.	7.9 per cent.
Elastic compressive strength	23.21 tons	21.13 tons
Ultimate "	71.24 "	89.30 "

Strength of Steel as affected by its Chemical Composition.

TABLE 190 - BESSEMER STEEL (FOR TYRES) - CHEMICAL COMPOSITION AND TENSILE STRENGTH.
(J. O. Arnold—Summary.)

Chemical Composition						Tensile Strength.			Fracture.
Iron.	Carbon.	Chro- mium	Man- ganese.	Silicon	Sulphur.	Phos- phorus	Ultimate, in Tens. Sq. In. h	Exten- sion.	
Per cent	Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Tons.	Per cent	Per cent.
98.24	.28	...	1.25	.07	.08	.08	87	26	47
97.74	.25	...	1.75	.09	.12	.11	42.1	18	26.8
97.40	.28	.42	1.54	.08	.10	.09	49.8	15	26
97.69	.32	.30	1.46	.11	.05	.07	50	16	29
97.42	.28	.04	1.41	.11	.07	.07	50.4	10	13.8
SPRING STEEL.									
98.24	.50	...	1.10	.07	.00	.08	50.8	14.9	31.4
							69.4	10.9	30.0
							88.0	8.1	4.9
Description.									
Water hardened.									
Oil hardened.									

Gray granular.
Coarse and con-
cave.

Gray granular,
flat.

Finely crystal-
line, flat.

Coarse granular.
Crystalline.

The Table 190, gives the experimental results of tests of Bessemer tyre-steel, conducted by Mr. J. O. Arnold, with the chemical composition of the steels tested. These comprise samples containing various proportions of chromium and manganese, as well as of carbon. An example of spring steel is introduced in this Table, showing the hardening influence of water and of oil.

Another Table 191, of the transverse strength of steel rails, shows also the variations of transverse strength with the percentage of carbon. The rails were double headed, 5½ inches deep, weighing 86 pounds per yard: and whilst the carbon increased from 40 per cent. to 55 per cent., the ultimate loads were increased from 40 tons to 52½ tons.

TABLE 191.—TRANSVERSE STRENGTH OF STEEL RAILS IN RELATION TO THE CONSTITUENT CARBON.

Span 43·5 inches. Load applied at the middle.

Con- stituent Carbon.	Ultimate Strength.			Elastic Strength.			
	Load.	Deflection	Set.	Load.	Deflection	Set.	
Per cent.	Tons.	Inch.	Inch.	Tons.	Per cent.	Inch.	Inch.
40	40	3·94	3·74	15	37·5	·10	·01
46	40	2·64	2·34	20	50	·14	·05
49	50	4·18	3·77	22·5	45	·165	·08
50	52·5	4·68	4·28	22·5	43	·130	·01
55	52·5	4·40	4·02	25	48	·165	·04

TABLE 192.—TENSILE STRENGTH OF STEEL RAILS IN RELATION TO THE CONSTITUENT CARBON

Constituent Carbon.	Ultimate Tensile Strength, in Tons per Square Inch	Constituent Carbon.	Ultimate Tensile Strength, in Tons per Square Inch.
Soft Rails.		Hard Rails	
Per cent.	Tons.	Per cent.	Tons.
28	30·90	36	37·01
29	32·60	39	41·41
30	32·94	40	37·68
31	32·67	43	39·10
32	33·04	44	41·02
		45	44·00
		50	45·73
		57	50·42

Thirty Bessemer steel rails, manufactured at Barrow-in-Furness, comprising various proportions of constituent carbon, were tested for tensile strength, with the results given by Mr. J. T. Smith in Table 192, showing that the tensile strength increased from 30·9 tons to 50·42 tons per square inch, with the proportions of carbon from ·28 to ·57 per cent.

TABLE 193.—TENSILE STRENGTH OF STEEL IN RELATION TO THE CONSTITUENT CARBON.

Description of Steel.	Constituent Carbon (Approximate).	Breaking Weight per Square Inch.	Extension.
	Per cent.	Tons.	Per cent.
Webb steel	·20	28·0	···
Vickers No. 2	·33	30·4	9·8
„ No. 4	·43	34·0	9·8
„ No. 5	·48	37·5	8·9
„ No. 6	·53	42·5	8·0
„ No. 8	·63	45·0	7·1
„ No. 10	·74	45·5	5·0
„ No. 12	·84	55·0	8·0
„ No. 15	1·00	60·0	5·0
„ No. 20	1·25	69·0	4·4

The influence of the constituent carbon on the tensile strength of steel was well exemplified by Mr. T. Edward Vickers in 1861, as shown in the Table 193. To render the table fuller, the strength and constituent carbon of Mr. Webb's steel for boiler plates are prefixed, in the first line. The specimens of Mr. Vickers were made of crucible steel from Swedish iron. They were turned to a diameter of 1 inch for a clear length of 14 inches. It is shown that the ultimate tensile strength increases with the carbon from 28 tons, with $\frac{1}{5}$ th per cent. of carbon, to 69 tons per square inch with $1\frac{1}{4}$ per cent. of carbon.

M. Debauve gives the following evidence of the influence of the constituent carbon, in the case of steel bars tempered in oil :—

Constituent carbon } ·15, ·49, ·709, ·875 per cent.

Elastic limit · 20·32, 27·94, 43·18, 57·15 tons per square inch.

Ultimate strength	29·21, 46·45, 67·94, 67·31 tons per square inch.
Extension in inches	28, 12, 4, 1 per cent.

Strength of Long Round Steel Columns.

The safe working load for long round steel columns is given by means of the following formula.

$$W = 1400 \frac{d^3}{l^2} \quad (83)$$

W = safe load in cwts.

d = diameter of column in inches.

l = length of column between supports or brackets, in feet.

This formula is specially applicable to the case of hydraulic lifts, as well as to the case of fixed loads. It may be properly employed for columns of from 3 inches to 5 inches in diameter, and for lengths of from 25 feet up to 50 feet, for columns not less than 3 inches in diameter; and up to 80 feet for 5-inch columns. Table 194 has been calculated by means of the above formula.

TABLE 194. —SAFE LOAD ON LONG ROUND STEEL COLUMNS.

Diameter of Column.	Length of Column between supports, in Feet.								
	25	30	35	40	45	50	60	70	80
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
3	60·5	42·0	30·8	23·6	18·6	15·1	...	...	...
3½	76·8	53·4	39·2	30·0	23·7	19·2	...	...	...
3¾	96·0	66·7	49·0	37·5	29·6	24·0	16·7	...	...
4	143·0	99·6	73·1	56·0	44·2	35·8	25·0	...	...
4½	204·1	141·7	104·1	79·7	63·0	51·0	35·4	26·0	...
5	280·0	194·4	143·0	109·4	86·4	70·0	48·6	35·7	27·3

Transverse Strength of Steel.

Taking the ordinary standard of ultimate tensile strength, 32 tons per square inch, for steel, the formula for its ultimate transverse strength is.—

Ultimate Transverse Strength of Steel Beams of Rectangular Section, supported at the Ends, loaded at the Middle.

$$W = 37·3 \frac{b d^2}{l} \quad (84)$$

For some other values of tensile strength, the numerical coefficients annexed are to be substituted in this equation:—

Tons
Square inch

Aluminium brass, castings —

No. 1. Aluminium bronze, and zinc (extension, 1 to 14 per cent.)	23 to 27
No. 2. Aluminium bronze, and zinc (extension, 8 to 11 per cent.)	30 to 38
Brass, fine or yellow, 2 copper, 1 zinc	22
Brass tube, 62 copper, 38 zinc	46
" " 70 " 30 "	36
Mintz metal, 60 copper, 40 zinc	22
Bronze, ordinary (extension, 1·2 to 4 per cent.)	9·06 to 10·5

Delta metal: Copper $\frac{3}{4}$, zinc $\frac{1}{4}$, with 2 per cent. of iron —

Cast in sand (extension, 21·6 per cent.)	20·8
Hot rolled, $1\frac{1}{2}$ -inch bars (" 34·7 ")	33·2
" annealed (" 19·1 ")	29·8
Forged at dark red heat	36
Hammered or rolled cold upwards of	40
Gun metal, 12 copper, 1 tin	29·9
" 11 " 1 "	13·7
" 10 " 1 "	14·7
" 9 " 1 "	17·0

Manganese bronze: copper 88, tin 10, iron and manganese, 2. —

Cast under pressure (extension, 12·4 to 22 per cent.)	31·9 to 37
Rods rolled hot, (" 33·4 to 44·6 ")	29
annealed	
Rods rolled hot, (" 23·3 to 26·5 ")	31·4
from rolls	
Rods rolled hot, (" 11·5 ")	39
finished cold	
Plates rolled hot, (" 28·8 to 47·8 ")	30·1
annealed, with fibre	
Plates rolled hot, (" 23·2 to 34·1 ")	(28·5
annealed across fibre	30·8
Phosphor-bronze. (" 3·6 to 33·4 ")	9·7 to 22

Sterro metal (Dr. Anderson) —

Copper 10, iron 10, zinc 80	3·17
" 60, " 3, " 39, tin, 1·5	24
" 60, " 4, " 44, " 2:—	
Cast in sand	19·25
Cast in iron, annealed	24·15
Cast in iron, forged, red hot	31

Copper 60, iron 2, zinc 37, tin 1	Tons per Sq. In.
" 60, " 2, " 35, " 2	34
" 55, " 1.77, " 42.36, " .83	38
Cast	27
Forged red hot	84
Drawn cold	38

Ultimate Tensile Strength of Lead, Tin, Zinc, and Glass.

	Tons per Sq. In.
Lead, cast	.81
" sheet	.86
" pipe	1.00
Tin, cast	2.11
" banco	.95
" solder, soft (2 tin, 1 lead)	3.35
Zinc, cast	1.54
" sheet, with grain (London Zinc Mills) (extension, 14.2 per cent.)	14.6
Glass, flint, annealed	1.07
" green	1.29
" crown	1.14
" thin globes	2.23

TABLE 195.—ULTIMATE TENSILE STRENGTH OF WIRES.
(Mr. Kirkaldy.)

Wires from $\frac{1}{16}$ to $\frac{1}{4}$ inch thick, except Phosphor bronze,
 $\frac{1}{8}$ inch thick.

Wire.	Ultimate Tensile Strength per Square Inch.		Extension, annealed.	Twists in Five Inches of Length.	
	Unannealed.	Annealed.		Unannealed.	Annealed.
	Tons.	Tons.	Per cent.	Twists.	Twists.
Coke iron . . .	28.71	27.36	17	26	44
Charcoal iron . .	29.05	23.99	28	48	87
Steel . . .	54.07	33.32	10.9	*	79
Copper . . .	28.18	16.52	34.1	86.8	96
Brass . . .	36.23	28.01	36.5	14.7	57
Phosphor bronze, No. 1	71.21	26.27	46.6	13.3	66
" No. 2	67.46	28.86	42.8	15.8	60
" No. 3	62.12	24.15	44.9	17.3	53
" No. 4	53.98	23.83	42.4	13	124

* Of the eight pieces of steel tested, 3 stood 40 to 45 turns and 5 stood 14 to 4 turns.

TABLE 196. COMPARATIVE TENACITY OF METAL WIRE AT DIFFERENT TEMPERATURES.

The wires tested were about $\frac{1}{60}$ th inch thick, except the iron wires, which were $\frac{1}{135}$ th inch thick.

	Tons per Square Inch.		
	At 32° F.	At 212° F.	At 392° F.
Gold	11.50	9.85	8.25
Platinum	14.50	12.60	11.25
Copper	18.20	15.90	13.75
Silver	18.65	17.20	14.85
Palladium	23.30	20.75	17.85
Iron	131.75	124.70	134.5

The steel wire, $\frac{1}{10}$ inch thick, of the Brooklyn cable railway was proved to an average ultimate tensile strength of 70 tons per square inch, with an extension of 7.3 per cent.

RESISTANCE OF STONES AND OTHER BUILDING MATERIALS.

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRESS.

(Fairbairn.)

Stone.	Cubo. Inches.	Fractured at. Tons.	Crushed at. Tons.	Crushing Force.	
				Per Sq. In.	Per Sq. Ft.
				Tons.	Tons.
Greywacke, Pennsylvanian	2	18.1	30.2	7.5	1080
Granite, Mount Seretel	3	22.9	22.9	5.7	821
Gneiss	2	21.1	21.1	5.3	763
Granite, Bonar, Inverary	14	7.6	10.9	4.0	700
Limestone	14	7.7	8.0	3.8	547
Sandstone	1	1.4	1.6	1.6	230
"	2	4.0	5.5	1.4	202
Victoria Stone (granite and Portland cement, steeped in a solution of nitric acid).				3.74	634

Copper 60, iron 2, zinc 37, tin 1	Tons per Sq. In.
" 60, " 2, " 35, " 2	34
" 55, " 1.77, " 42.36, " .83 :—	38
Cast	27
Forged red hot	34
Drawn cold	38

Ultimate Tensile Strength of Lead, Tin, Zinc, and Glass.

	Tons per Sq. In.
Lead, cast	.81
" sheet	.86
" pipe	1.00
Tin, cast	2.11
" banco	.95
" solder, soft (2 tin, 1 lead)	3.35
Zinc, cast	1.34
" sheet, with grain (London Zinc Mills) (extension, 14.2 per cent.)	14.6
Glass, flint, annealed	1.07
" green	1.29
" crown	1.14
" thin globes	2.23

TABLE 195 — ULTIMATE TENSILE STRENGTH OF WIRES.
(Mr. Kirkaldy.)

Wires from $\frac{1}{16}$ to $\frac{1}{4}$ inch thick, except Phosphor bronze,
 $\frac{1}{8}$ inch thick.

Wire.	Ultimate Tensile Strength per Square Inch.		Extension, an- nealed.	Twists in Five Inches of Length.	
	Un- annealed	An- nealed		Un- annealed	An- nealed
	Tons	Tons.	Per cent	Twists.	Twists.
Coke iron . . .	28.71	27.36	17	26	44
Charcoal iron . . .	29.05	23.99	28	48	87
Steel	54.07	33.32	10.9	*	79
Copper	28.18	16.52	34.1	80.8	96
Brass	36.23	23.01	36.5	14.7	57
Phosphor bronze, (
No. 1)	71.21	26.27	46.6	13.3	66
" No. 2	67.46	28.86	42.8	15.8	60
" No. 3	62.12	24.15	44.9	17.3	53
" No. 4	53.98	23.83	42.4	13	124

* Of the eight pieces of steel tested, 3 stood 40 to 45 turns and 5 stood 1½ to 4 turns.

TABLE 196. COMPARATIVE TENACITY OF METAL WIRE AT DIFFERENT TEMPERATURES.

The wires tested were about $\frac{1}{60}$ th inch thick, except the iron wires, which were $\frac{1}{15}$ th inch thick.

	Tons per Square Inch.		
	At 32° F.	At 212° F.	At 302° F.
Gold	11.90	9.85	8.25
Platinum	14.50	12.60	11.25
Copper	18.20	15.90	13.75
Silver	18.05	15.20	11.85
Palladium	23.30	20.75	17.85
Iron	131.75	124.70	134.5

The steel wire, $\frac{1}{16}$ inch thick, of the Brooklyn cable railway was proved to an average ultimate tensile strength of 70.4 tons per square inch, with an extension of 7.3 per cent.

RESISTANCE OF STONES AND OTHER BUILDING MATERIALS.

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRESS.

(Fairbairn.)

Stone.	Cube. Inches.	Fractured at. Tons.	Crushed at. Tons.	Crushing Force.	
				Per Sq. In.	Per Sq. Ft.
Greywacke, Pentamadunpur	2	18.4	30.2	7.5	1080
Granite, Mount Norfol	2	22.9	22.9	5.7	821
Syelite	2	21.1	21.1	5.3	763
Granite, Bonar, Jyverary	1½	7.8	16.9	4.9	706
Limestone	1½	7.7	8.6	3.8	547
Sandstone	1	1.4	1.6	1.6	230
"	2	4.3	6.5	1.4	202
Victoria Stone (granite and Portland cement, steeped in a solution of lime).				3.71	524

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRESS
(continued).

(L. Clark.)

RED SANDSTONE, average weight, 130·6 lbs. per cubic foot ;
17 cubic feet per ton.

Specimen.	Cube.	Crush- ing Load.	Load per Sq. In.	Load per Sq. Ft.
	Inches.	Tons.	Tons.	Tons.
No. 6. Quite dry, set between boards	3	8·21	·91	131·0
No. 7. Set in cement, moderately damp	3	5·16	·57	82·1
No. 8. Set in cement, very wet	3	4·36	·48	69·1
No. 9. Set in cement.	6	63·07	1·75	252·0
Average			·93	133·8

Note.—Gave way suddenly.

ANGLESEA LIMESTONE. Weight, 165·25 lbs. per cubic foot ;
13½ cubic feet per ton.

No. 11. Set between boards	3	26·58	2·95	424·8
No. 12. Set between boards } to crack at "25 tons" began	3	32·30	3·60	518·4
No. 13. Set between boards.	3	30·95	3·44	495·4
No. 14. Three separate 1 inch cubes } set between boards	...	9·37	3·12	449·8
Average			3·28	472·8

(Debauve.)

	Weight per Cubic Foot.	Crushing Force per Sq. Inch.	Crushing Force per Sq. Foot.
	Pounds.	Tons.	Tons.
Granite : hard, fine grain	...	6·4 to 9·6	922 to 1382
" " coarse grain	...	4·4 to 6·4	634 to 923
" slowly decomposes in water :			
fine grain	...	3·8 to 5·7	547 to 821
coarse grain	...	2·5 to 3·8	360 to 547
Basalt	...	12·1	1742
Lava	112·3	2·7	389
Porphyry	...	8·2	1181
Jasper	...	11·7	1685
Sandstone : hard	131 to 156	2·2 to 4·9	317 to 706
" semi-hard, or tender	118·5 to 131	·51 to 1·9	73 to 274
Limestone : for building	87·4 to 174·7	·13 to 7·6	19 to 1094
" hard	137 to 175	1·4 to 7·6	202 to 1094
" soft	87·4 to 137	·51 to 1·4	73 to 202

TABLE 198. —RESISTANCE OF SLATES TO RUPTURE.
(Debaucé)

Pieces of Anjou slate, 10 inches square, resting by their four edges on a flat frame bearing, were loaded on a central spot 4 inches square.

Thickness.		Breaking Load		Thickness.		Breaking Load	
Millims.	Inch.	Kilogs.	Pounds.	Millims.	Inch.	Kilogs.	Pounds.
1	0.394	8	17.6	5	1.968	120	264
2	0.787	35	77	6	2.362	150	330
3	1.181	50	110	7	2.756	170	374
4	1.575	90	198				

TABLE 199.—RESISTANCE OF BRICKS AND BRICKWORK TO CRUSHING STRESS.

Description.	Crushing Force per Square Inch.	Crushing Force per Square Foot.
	Tons.	Tons.
Red	358	51.6
Yellow-faced, baked	446	64.2
" burned	643	92.6
Gault clay, pressed	1.111	160
" wire-cut	884	127.3
" perforated	1.180	169.9
Stock	1.044	150.3
Fareham red	2.500	360
Staffordshire blue, pressed with frogs	3.100	446.4
" rough, with out frogs	3.275	471.6
" Hamblet's (Kirkcaldy)	7.390	824
Stourbridge fireclay	718	103.4
Tivulale blue	620	89.3
Silex ferrine	7.332	1056.2
Vitrified granite, Candy	3.091	445.2
Terra-cotta fire and sound proof (before cracking)	315	45.3
Glass		

TABLE 199.—RESISTANCE OF BRICKS AND BRICKWORK TO CRUSHING STRESS (*continued*).

Cemented Brickwork. Best quality.					
	Cube.	Weight.	Crush- ing Load.	Load per Square Inch.	Load per Square Foot.
	Inches.	Pounds.	Tons.	Tons.	Tons.
No. 1, 9-inch cube set between deal boards	9	54	19.94	.25	36.0
No. 2, 9-inch cube in cement	9	53	22.15	.27	38.9
No. 3, 9-inch cube in cement	9	52	16.42	.20	28.8
No. 4, 9½-inch cube in cement	9½	55½	21.72	.27	38.9
No. 5, 9-inch cube, be- tween boards	9	54½	15.50	.19	27.4
Average				.23	34.0
<i>Note.</i> —Irregular cracks occurred a considerable time before the blocks gave way.					

TABLE 200.—RESISTANCE OF PORTLAND CEMENT CONCRETE BLOCKS TO CRUSHING STRESS.

(Grant.)

Portland Cement Concrete Blocks : 12 inch cubes
compressed, 12 months old.

	Cube.	Weight.	Crush- ing Load.	Load per Square Inch.	Load per Square Foot.
	Inches.	Pounds.	Tons.	Tons.	Tons.
ent to 1 sand and)	12	...	170.5	1.18	170.5
gravel)	12	...	115.5	.81	115.5
"	12	...	91.0	.68	91.0
"	12	...			

TABLE 201.—ULTIMATE TENSILE STRENGTH OF STONES.
(Debaucé.)

Stone.	Tensile Resist- ance per Square Inch.	Tensile Resist- ance per Square Foot.
	Tons.	Tons.
Basalt (Auvergne)	49	70·6
Portland limestone	38	54·7
Compact "	20	29
Silicious "	14	20·2
Oolitic "	9·9	13
Brick of good quality	11 to 13	16·8 to 18·7
Bagneux rock (near Paris)	9·9	13
Soft stone (de Vergelet)	4·5	6·5
Stoneware pipes	21 lb to 350 lb. or 15 ton	135 to 21·6

TABLE 202 —Average Working Loads for Building Material
and Structures (Austrian Association of Engineers).

(1) WEIGHT OF MATERIALS.

Material.	Lbs. per Cubic Foot.
TIMBER	
Oak	50
Pine	44
Fir	44
Red pine	41
Pitch pine	41
Larch	44
METAL:	
Wrought iron (per cubic inch, 28 lb.)	470
Cast iron (" 27 lb.)	468
Lead (" 40 lb.)	711
Copper (" 32 lb.)	555
Zinc (" 26 lb.)	449
BRICK AND STONE	
	(Wet.) (Dry)
Hollow bricks	87 75
Ordinary "	106 94
Flemish "	125 119
Rubble Masonry	150
Concrete	150
Ashlar sandstone	150 to 156
" limestone	162 to 166
Granite	175

TABLE 202.—(1) WEIGHT OF MATERIALS (*continued*).

Material.	Lbs per Cubic Foot.
VARIOUS MATERIALS:—	
Broken stone	87
Fine dry sand	77
Coarse dry sand	84
Clay, loam, dry	94
" wet	119
Lime mortar, cement mortar	106
Asphalt, pure	69
" concrete	100
" compressed	113
Gypsum	72
Window glass	165

TABLE 202.—(2) WORKING STRESS.

Material.	Tensile, per Square Inch.	Compressive, per Square Inch.
	Tons.	Tons.
Wrought iron	6.0	6.0
Cast iron	1.5	4.5
Oak . . . . .	.60	.42
Pine . . . . .	.54	.36
Fir . . . . .	.42	.36
Red pine . . . . .	.42	.33
Larch . . . . .	.42	.33

TABLE 202.—(3) WORKING LOADS ON FOUNDATIONS.

Foundation.	Tons per Square Foot.
Moist clay and sand (protected against lateral spreading)	1.36
Coarse sand and dry clay	2.27
Firm bedded broken stones on dry clay	3.18
Loose impermeable beds, with piling	1.42
" " " and concrete	2.73

TABLE 202. (4) WORKING LOAD ON STONE WALLS AND COLUMNS.

	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Granite, porphyry	712	570	287
Hard stone	356	285	...
Medium stone	214	142	...
Soft stone	108	...	...

TABLE 202.—(5) WORKING LOADS ON BRICKWORK,
MASONRY, &c.

Description of Work.	Walls not less than 18 inches thick, and columns where diameter is at least than one sixth of height.		Walls under 18 inches thick, and columns where diameter is from one-sixth to one-eighth of height.		Columns where diameter is from one-eighth to one-twelfth of height.	
	Lbs. per Sq. inch.		Lbs. per Sq. inch.		Lbs. per Sq. inch.	
Brickwork in lime mortar	72		86			
" cement	108		72			
Portland cement	142		108		44	
Rubble masonry in lime mortar	58					
" cement	72					
Pressed bricks in	128		114		108	
" Portland cement	172		142		114	
Flemish bricks in	214		172		142	
Portland cement concrete	100					

TABLE 202.—(6) WORKING LOADS ON FLOORS, STAIRS, AND ROOFS.

Location	Lbs. per Square Foot.			
Live loads on floors.—				
Attic floors	30.8			
Dwelling-room floors	51.2			
Libraries, dancing saloons, &c.	71.7			
Stairs and passages	82.0			
Business premises, workrooms, &c.	92.2			
Hay and fruit lofts	102.5			
Workshops and warehouses	112.7			
Theatres, concert rooms, warehouses and workshops with heavy machinery or special loads	Loads specially adapted.			
Dead loads, snow and wind, on roofs—in lbs. per square yard on horizontal plane				
	Slope of Roof	Dead Load	Snow and Wind.	Total.
		Lbs.	Lbs.	Lbs.
Single tile roof	1 horizontal to 1.25 vertical	27.7	25.6	53.3
Double "	1 to 1.25	33.8	25.6	59.4
Single slate	1 " 2.25	15.4	19.5	34.9
Double "	1 " 2.25	23.6	19.5	43.1
Zinc or galvanized iron	1 " 4	8.2	15.4	23.6
Carton-Pierre	1 " 4	8.2	15.4	23.6
Sheet iron or iron purlins	1 " 5	4.1	15.4	19.5

TABLE 202.—(7) SNOW AND WIND.

Weight of snow on horizontal surface	allow 15.5 lbs. per sq foot.
Wind pressure on surface at right angles to line of impact	" 24.6 " "
Do do in specially exposed positions	" 31.0 " "

TABLE 202.—(4) WORKING LOAD ON STONE WALLS AND COLUMNS.

Material.	Thick Ashlar walls and single bed-stones and columns, where diameter is not less than half the height.	Block-in-course work and columns where diameter is from half to one-twelfth of height.	Columns where diameter is less than one-twelfth of height.
	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Granite, porphyry	712	470	285
Hard stone	356	235	...
Medium stone	214	142	...
Soft stone	108	108	...

TABLE 202.—(5) WORKING LOADS ON BRICKWORK, MASONRY, &c.

Description of Work.	Walls not less than 18 inches thick, and columns where diameter is not less than one-sixth of height.	Walls under 18 inches thick, and columns where diameter is from one-sixth to one-eighth of height.	Columns where diameter is from one-eighth to one-twelfth of height.
	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Brickwork in lime mortar	72	36	...
" cement	108	72	...
" Portland cement	142	108	44
Rubble masonry in lime mortar	58	...	...
" cement	72	...	...
Pressed bricks in	128	114	108
" Portland cement	172	142	114
Flemish bricks in	214	172	142
Portland cement concrete	100	...	...

TABLE 202.—(6) WORKING LOADS ON FLOORS, STAIRS, AND ROOFS.

Location.	Lbs. per Square Foot.
Live loads on floors .	
Attic floors	30.8
Dwelling-room floors	51.2
Libraries, dancing saloons, &c.	71.7
Stairs and passages	82.0
Business premises, workrooms, &c.	92.2
Hay and fruit lofts	102.5
Workshops and warehouses	112.7
Theatres, concert rooms, warehouses and workshops with heavy machinery or special loads	Loads specially adapted.
Dead loads, snow and wind, on roofs—in lbs. per square yard on horizontal plane —	

TABLE 202. —(7) SNOW AND WIND.

Weight of snow on horizontal surface	allow 15.5 lbs. per sq foot.
Wind pressure on surface at right angles to line of impact	
Do. do. in specially exposed positions	

RIVETED JOINTS IN BOILER PLATES.

The proportions by which maximum strength of riveted joints is attained, are given in Table 203, in terms of the thickness of plates and diameter of rivets.

TABLE 203 — PROPORTIONS OF RIVETED JOINTS OF MAXIMUM STRENGTH.

thickness of plates	= unity
diameter of rivets	= thickness of plate $\times 2$.
pitch of rivets (single riveting)	= thickness of plate $\times 5\frac{1}{2}$.
pitch of rivets (double riveting)	= thickness of plate $\times 4$.
diagonal pitch (double riveting)	= longitudinal pitch $\times \frac{3}{4}$.
"spacing" (double riveting)	= longitudinal pitch $\times \frac{5}{6}$, or $\frac{9}{10}$.
lap (single riveting)	= thickness of plate $\times 6$.
lap (double riveting)	= thickness of plate $\times 10\frac{1}{2}$, or 12 .

In conformity with the above proportions, the upper part of the following Table 204, shows the dimensions of rivet-joints for plates from $\frac{1}{16}$ inch to $\frac{1}{4}$ inch thick, the last of which $\frac{1}{4}$ inch rivets are provided. This is the largest size of rivets ordinarily used in boiler construction. For plates thicker than $\frac{1}{4}$ inch the joints are to be made with $\frac{1}{2}$ inch rivets, suitably pitched for equal resistance of net section of plate and shearing resistance of rivets; and, therefore for maximum strength when $\frac{1}{2}$ inch rivets are used, as given in the lower part of the Table.

For boiler plates of iron and of steel $\frac{1}{2}$ inch in thickness, the breaking or ultimate strength of riveted joints in parts of the of the entire plate are given in the Table 205. These relative values are deduced from the results of numerous experiments. The diameter of rivets is not that of the rivet holes, as adopted in calculation.

The percentage of breaking strength in the last two columns of Table 205 may be applied for other thicknesses of plate up to $\frac{1}{4}$ inch, as in Table 204, upper part; except the values for single-riveted lap and singlewelt, which for thinner than $\frac{1}{4}$ inch plates are higher, and for thicker plates are lower. For plates thicker than $\frac{1}{4}$ inch, as in the lower part of Table 204, the breaking strengths may be taken as approximately in the proportion of the net sections of plate as percentages of the entire section. These are here subjoined in Table 206.

TABLE 204.—DIMENSIONS OF RIVET JOINTS.
(Plates $\frac{1}{8}$ inch to $\frac{11}{16}$ inch thick).

Thickness of Plates.	Diameter of Rivets.	Pitch of Rivets.				Lap.	
		Single Riveting.	Double Riveting.			Single Riveting.	Double Riveting.
			Longitudinal.	Diagonal.	Spacing.		
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	1	$\frac{3}{4}$	$\frac{7}{16}$	$\frac{3}{4}$	$1\frac{1}{16}$
$\frac{1}{16}$	$\frac{1}{16}$	1	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{16}$	$1\frac{1}{4}$	2
$\frac{1}{8}$	$\frac{1}{8}$	$1\frac{1}{4}$	2	$1\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$2\frac{3}{8}$
$\frac{3}{16}$	$\frac{3}{16}$	$1\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{16}$	$1\frac{3}{4}$	$3\frac{1}{4}$
$\frac{1}{4}$	$\frac{1}{4}$	2	3	$2\frac{1}{4}$	$1\frac{1}{16}$	$2\frac{1}{4}$	$3\frac{1}{2}$
$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{3}{8}$	2	$2\frac{3}{8}$	$4\frac{1}{8}$
$\frac{3}{8}$	$\frac{3}{8}$	$2\frac{3}{4}$	4	3	$2\frac{1}{4}$	3	$4\frac{1}{2}$
$\frac{7}{16}$	$\frac{7}{16}$	3	$4\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{3}{8}$	$3\frac{3}{8}$	$5\frac{1}{8}$
$\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{2}$	5	$3\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{3}{4}$	$6\frac{1}{2}$
$\frac{5}{8}$	$\frac{5}{8}$	$3\frac{3}{4}$	$5\frac{1}{2}$	4	$3\frac{1}{8}$	4	7
$\frac{3}{4}$	$\frac{3}{4}$	3.475	5.156	3.867	2.900	4	7
$\frac{7}{8}$	$\frac{7}{8}$	3.318	4.866	3.650	2.737	$4\frac{1}{4}$	$7\frac{1}{4}$
$\frac{15}{16}$	$\frac{15}{16}$	3.179	4.616	3.462	2.597	$4\frac{1}{2}$	$7\frac{1}{2}$
1	1	3.059	4.401	3.301	2.475	$4\frac{3}{4}$	$7\frac{3}{4}$
$1\frac{1}{16}$	$1\frac{1}{16}$	2.953	4.212	3.159	2.370	$4\frac{7}{8}$	$7\frac{7}{8}$
$1\frac{1}{8}$	$1\frac{1}{8}$	2.861	4.045	3.034	2.275	$4\frac{7}{8}$	$7\frac{7}{8}$
$1\frac{1}{4}$	$1\frac{1}{4}$	2.778	3.895	2.921	2.191	$4\frac{7}{8}$	$7\frac{7}{8}$

TABLE 205. ULTIMATE RELATIVE STRENGTH OF RIVETED JOINTS IN $\frac{3}{8}$ -INCH BOILER PLATES.

3-Inch Plate Joint.	Thickness of Plate.	Rivets				Breaking Strength in Parts of that of Whole Plate.	
		Diameter	Pitch Longitudinally	Nominal net sec. of plate + parts of that of whole plate		Iron	Steel.
	Inch	Inch	Inches.	Per cent.		Per cent.	Per cent.
Single-riveted lap	$\frac{3}{8}$	$\frac{3}{8}$	2	62.5		50	60
" single welt	$\frac{3}{8}$	$\frac{3}{8}$	2	62.5		50	58
" double welt	$\frac{3}{8}$	$\frac{3}{8}$	2	62.5		60	65
Double-riveted lap	$\frac{3}{8}$	$\frac{3}{8}$	3	75		70	80
" single welt	$\frac{3}{8}$	$\frac{3}{8}$	3	75		65	75
" double welt	$\frac{3}{8}$	$\frac{3}{8}$	3	75		72	80

Note: 'Spacing' is the pitch of the longitudinal centres of rivets in double-riveted joints.

TABLE 206.—NET PLATE SECTION OF PLATES $\frac{1}{4}$ INCH AND UPWARDS IN THICKNESS.

Thickness of Plate.	Diameter of Rivets.	Net Plate Section in parts of Whole Section.	
		Single Riveting.	Double riveting.
Inches.	Inches.	Per cent.	Per cent.
$\frac{3}{4}$	$1\frac{3}{8}$	60·4	78·5
$\frac{13}{16}$	$1\frac{3}{8}$	58·6	71·7
$\frac{7}{8}$	$1\frac{3}{8}$	56·8	70·2
$\frac{15}{16}$	$1\frac{3}{8}$	55·0	68·8
1	$1\frac{3}{8}$	53·4	67·4
$1\frac{1}{16}$	$1\frac{3}{8}$	51·9	66·0
$1\frac{1}{8}$	$1\frac{3}{8}$	50·5	64·7

The most suitable pitches for given diameters of rivets, or, on the contrary, the most suitable diameters of rivets for given pitches, in order to form joints of equal resistance, may be calculated by means of the following formulæ (92) and (93), as, of course, pitches and diameters may be adopted other than those which are above-recommended :—

$$\text{single riveted lap joint :—} \begin{cases} p = \cdot 835 \frac{d^2}{t} + d & \dots \dots (92) \\ d = \sqrt{1\cdot 20 \, t \, p + \cdot 36 \, t^2} - \cdot 60 \, t & \dots (93) \end{cases}$$

These formulæ are applicable also for single-riveted single-welt and double-welt joints.

$$\text{double riveted lap joints :—} \begin{cases} p = 1\cdot 5 \frac{d^2}{t} + d & \dots \dots (94) \\ d = \sqrt{\frac{2}{3} \, t \, p + \frac{t^2}{9}} - \frac{t}{3} & \dots (95) \end{cases}$$

These formulæ are applicable also for double-riveted single-welt and double-welt joints.

BOILER SHELLS.

The bursting strength per square inch of a cylindrical boiler shell is twice as much longitudinally, that is to say, parallel to the axis, as it is transversely.

$$\text{Bursting pressure} \quad p = \frac{4480 \, t \, s}{d} \quad \dots \dots (96)$$

$$\text{thickness of plates} \quad t = \frac{d \, p}{4480 \, s} \quad \dots \dots (97)$$

$$\text{ultimate tensile strength of plates } s = \frac{dp}{4480t} \quad (98)$$

d = internal diameter, in inches.

t = thickness of plate, in inches.

s = ultimate tensile strength of plate, in tons per square inch.

p = effective steam pressure, in pounds per square inch.

When the shell is constructed with riveted joints, the tensile strength s is to be reduced in the ratio of the ultimate strength of the whole plate to that of the joint.

The resistance of a hollow sphere to internal pressure is twice as much as that of a tube of equal diameter and equal thickness.

Strength of Ends of Cylindrical Steam Boilers.

For a flat end-plate forming the termination of a cylindrical shell, unstayed or unsupported except at the circumference, the ultimate elastic deflection under internal pressure is given by the formulæ :—

$$\delta = \frac{\text{radius}}{22} = \frac{r}{22} \quad (99)$$

$$\delta = \frac{\text{diameter}}{44} = \frac{d}{44} \quad (100)$$

δ = deflection at the centre in inches.

r = radius of the cylinder, in inches.

d = diameter of the cylinder in inches.

The relative internal pressure and stress in the end-plate strained to the elastic limit, are given by this formula :—

$$p = \frac{815ts}{d} \quad (101)$$

p = effective internal pressure, in lbs. per square inch.

t = thickness of end-plate, in inches.

s = tensile stress in end-plate, in tons per square inch at the elastic limit.

This formula is applicable for steel plates, as for iron plates, taking the elastic limit to be the same for both metals, namely, $\frac{1}{1000}$ th of the length. The elastic strength, s , is, for iron, 12 tons ; for steel 14 tons per square inch. Substituting these values in formula (101), the final formulæ are derived for the elastic strength of circular flat end-plates of iron and of steel, of uniform thickness, fastened at the circumference, exposed to *bulging pressure uniformly distributed* :—

for iron,
$$p = 10,000 \frac{t}{d} \quad (102)$$

for steel,
$$p = 11,500 \frac{t}{d} \quad (103)$$

p = bulging pressure, in lbs. per square inch.

t = thickness of the plate, in inches.

d = diameter of the plate, in inches, measured to the circular line of junction.

Flat Cast-iron Ends.

The elastic strength of flat cast-iron ends, adopting an extension of $\frac{1}{1000}$ th part of the length, as for iron and steel, corresponding to a tensile stress of 5 tons per square inch, is expressed by the formulæ :—

$$\delta = \frac{d}{44} \quad (104)$$

$$p = 4000 \frac{t}{d} \quad (105)$$

δ = deflection at centre, within the elastic limit, in inches.

d = diameter of the line of fastening, in inches.

t = thickness of the plate in inches.

p = elastic bulging pressure, in lbs. per square inch, uniformly distributed.

For cast-iron of stronger quality, the co-efficient in formula (105) is to be increased in proportion.

Segmental Ends.

The relation of the internal pressure and stress in a segmental or spherical end of a cylindrical shell, is given by the formula :—

$$p = \frac{8960ts}{r^2 + v} \quad (106)$$

p = internal pressure, in lbs. per square inch.

t = thickness of segmental end, in inches.

s = tensile stress in the plate, in tons per square inch.

r = radius of the circular junction, in inches.

v = versed sine or rise of the segment, in inches.

Substituting for the values of s : 12 tons for wrought iron.

94 tons for steel, and 5 tons for cast iron, the formula becomes . —

$$\text{Wrought iron,} \quad p = \frac{108,000t}{\frac{r^2}{v} + r} \quad . \quad . \quad . \quad (107)$$

$$\text{Steel,} \quad p = \frac{125,000t}{\frac{r^2}{v} + r} \quad . \quad . \quad . \quad (108)$$

$$\text{Cast-iron,} \quad p = \frac{45,000t}{\frac{r^2}{v} + r} \quad . \quad . \quad . \quad (109)$$

The versed sine or rise at the centre of a spherical segment having the same elastic strength as the body of the cylinder, measured by the internal pressure, is, say, one-fourth of the radius of the end of the cylinder, or one-eighth of its diameter.

Strength of stayed flat plates of steam boilers.

The relative internal pressure and stress in a flat-stayed plate, strained to the elastic limit, are given by the formula . —

$$p = \frac{407ts}{d} \quad . \quad . \quad (110)$$

p = internal pressure in lbs. per square inch.

t = thickness of the plate in inches.

d = clear distance apart between the bolts in rectangular arrangement.

s = tensile stress in the plate, in tons per square inch, at the elastic limit.

When the pitches of the staybolts, vertically and transversely, are not equal to each other, the greater clear distance is to be taken for calculation.

Reducing the above formula (110) for iron and for steel plates, of which the values of s are taken as 12 tons and 14 tons respectively, and so inverting the formulae to find the thickness of plate, and the clear distance apart of the staybolts, the following formulae are obtained . —

$$\begin{array}{ll} \text{For iron.} & \text{For steel.} \\ p = 5,000 \frac{t}{d} & p = 5,700 \frac{t}{d} \end{array} \quad . \quad . \quad (111)$$

$$t = \frac{pd}{5,000} \quad . \quad . \quad t = \frac{pd}{5,700} \quad . \quad . \quad (112)$$

$$d = \frac{5,000t}{p} \quad . \quad . \quad d = \frac{5,700t}{p} \quad . \quad . \quad (113)$$

The proper diameter of screwed stay bolts, at the base of thread, strained to the elastic limit, simultaneously with plate, is given by formula :—

$$d' = .0024 \sqrt{P P' p} \quad (11)$$

d' = diameter of staybolts, at base of thread.

P = pitch of staybolts between centres, longitudinally.

P' = " " " transversely.

p = maximum effective elastic pressure, in lbs. per square inch, on the plate.

s = elastic tensile strength of staybolts, in tons per square inch.

For bolts of iron, steel, and copper, having respective 12 tons, 14 tons, and 8 tons, elastic tensile strength per square inch, the special formulae for the proper diameter of the staybolts, at the base of the thread, are . —

$$\text{Iron } d' = .00069 \sqrt{P P' p}, \text{ or } d' = \frac{\text{When } P' = P}{.00069} \sqrt{p} \quad (12)$$

$$\text{Steel } d' = .00064 \sqrt{P P' p}; \text{ or } d' = .00064 P \sqrt{p} \quad (13)$$

$$\text{Copper } d' = .00084 \sqrt{P P' p}, \text{ or } d' = .00084 P \sqrt{p} \quad (14)$$

Collapsing Resistance of furnace-tubes.

Plain furnace-tubes of Lancashire and Cornish steam boilers, without stiffening joints, have the maximum resistance to collapsing pressure under steam, according to the formula :—

$$p = \frac{200,000 t^3}{d^3} \quad (15)$$

p = collapsing pressure, in lbs. per square inch.

t = thickness of the plates of the furnace-tube in inches.

d = internal diameter of the furnace tube in inches.

This formula is applicable to furnace-tubes of lengths over 9 feet. Tubes of shorter length derive natural assistance from the end fastenings.

Segmental Crowns of furnaces.

The elastic resistance of a segmental crown of a cylindrical furnace, to collapsing pressure externally may be formulated

in the same terms as the resistance to bursting pressure internally, here repeated :

$$p = \frac{8960 t s}{r^2 + v} \quad (119)$$

t = thickness of plate, in inches.

r = radius of circular junction, in inches.

v = versed sine, or rise of segment, in inches.

p = external collapsing pressure, in lbs per square inch.

s = compressive stress in the segment, in tons per square inch.

For the application of this formula, it is assumed that the spherical segment is perfectly formed. A segment of which the rise is one-eighth of the diameter of the cylindrical base is equally stressed with the base, under equal external pressure per square inch.

When the spherical segment is a hemisphere, made of plates equal in thickness to those of the cylinder, it is stressed to only half the extent per square inch to which the cylinder is stressed.

Hydraulic, Steam, and other Hollow Cylinders.

The resistance of, say, a hydraulic ram, to bursting pressure, is unequally distributed over the transverse section of the ram, being a maximum at the interior surface, diminishing radially to a minimum at the outer surface. The inequality of active resistance arises from the stretching of the material exposed to pressure, up to and beyond the elastic limit.

The formulas for resistance, in their most general form, are as follows :—

$$p = s \times \text{hyp log. R.} \quad (120)$$

$$s = \frac{p}{\text{hyp log. R.}} \quad (121)$$

$$\text{hyp log. R.} = \frac{p}{s} \quad (122)$$

$$d' = d \times R \quad (123)$$

$$t = \frac{d(R-1)}{2} \quad (124)$$

d = inside diameter, in inches.

d' = outside diameter, in inches.

p = internal pressure in tons per square inch.

s = maximum tensile stress, in tons per square inch.

R = ratio of outside diameter to inside diameter, or $\frac{d'}{d}$.

Note.—The pressure and stress may be expressed in hundred weights or in pounds.

In cases where the internal tensional stress on the material exceeds the elastic limit, the formulas are to be taken as only approximate. But it is believed that in such cases they are substantially correct for practical purposes. They are taken as correct for maximum tensional stress not exceeding the elastic limit.

The average tensional stress on the metal is equal to $\frac{p d}{d' - d}$.

That is to say, it is equal in tons per square inch to the product of the inside diameter by the internal pressure in tons per square inch, divided by the difference of the inside and outside diameters.

Example.—To find the bursting pressure of a cast-iron cylinder 8 inches in diameter inside, and 25 inches outside, the ultimate tensile strength of the metal being 7 tons per square inch. The ratio of the diameters is $(25 : 8 =) 3.125$, of which the hyperbolic logarithm is 1.1378. By formula (120) the bursting pressure is $(7 \times 1.1378 =) 7.96$ tons per square inch. The average stress over the whole sectional area of the metal is equal to $(8 \times 7.96) \div (25 - 8) = 3.75$ tons per square inch of section of metal.

2nd Example.—To find the bursting pressure of a hydraulic tube $1\frac{1}{4}$ inches in bore, $\frac{3}{8}$ inch thick; the direct ultimate tensile strength being 22 tons per square inch. The ratio of the outside and inside diameters is $(2\frac{1}{4} \div 1\frac{1}{4} =) 1.33$, the hyperbolic logarithm of which is .2852. By formula (120), the bursting pressure is 6.27 tons, or 14,040 pounds per square inch. The tube had been proved to a pressure of 11,000 pounds without failure.

In cases where the diameter is considerable in relation to the thickness, the transverse resistance to bursting pressure is taken as equal to the direct tensile strength per square inch of sectional area, according to the common rules already given.

WIRE ROPES AND HEMP ROPES.

The comprehensive Tables 207 to 211, of the weight and strength of wire ropes manufactured by Messrs. Dixon, Corbett and L. S. Newall & Co., comprise quantities varying from annealed iron having an ultimate tensile strength of 25 tons per square inch, and charcoal iron wire of 34 tons.

square inch, to special or extra plough steel wire of 150 tons. The 'patent steel' is crucible steel or open hearth steel hardened and tempered by a special process. The breaking strengths have been carefully ascertained. They are based on the most common system of construction: round ropes of 6 strands of 7 wires each, or 6 strands of 6 wires each. In the first there are 6 wires over a central wire, in the second, 6 wires over a hemp core. With such proportions, the cylindrical form is best maintained, and spacing is most readily effected. But ropes are made with from 3 to 12 strands. Wires vary from .010 inch to .212 inch in diameter for 6-strand ropes of 7 wires in each strand. But conductor or guide-ropes of 7 wires forming a strand have been made of $\frac{3}{8}$ inch rods.

Tables 212 and 213 give the sizes and strength of hemp ropes by Messrs. Dixon & Corbitt and R. S. Newall & Co. For the dimensions of cotton ropes, the same firm assume that cotton is equal in strength to hemp, and for coir ropes, that coir, or cocoa-hire, is of half the strength.

For vertical winching at a high speed, they adopt one-tenth of the breaking stress as a safe working load. But the load may, with suitable working conditions, be increased to a value of one-eighth. The gross weight hanging over the pulley is taken as the working load.

For hauling, the working load is usually taken by them at one-sixth of the breaking stress, and the following form of calculation for determining the proper size of rope, has been found by experience to be satisfactory.—Take an inclined plane, say, 800 yards in length, load, 20 tons; maximum inclination of road, 7 degrees, or 1 in 8.14.

Calculation for Resistance.

	ewts.	lbs.
Gravity of load, 20 tons \times 272.25 lbs. per ton	49	0 16
Friction of load, 20 tons \times 20 lbs. per ton	3	2 8
Gravity of rope, 800 yards, at 2 lbs. per yard,		
1600 lbs. \div 8.14	1	3 1
Friction of rope, 1600 lbs. \times .20	0	2 24
Total working stress or load	53	0 21

TABLE 207.—ROUND WIRE ROPES, WEIGHT

Sizes.		Weights per Fathom.		Cast-iron Rope.			Bessemer Steel, or Ingot Iron.			Phosphor Bronze.		
Diameter.	Circumference.	6 Strands.		Breaking Strain.	Working Load.		Breaking Strain.	Working Load.		Breaking Strain.	Working Load.	
		Wires.	Wires.		P. t.	Inch.		P. t.	Inch.		P. t.	Inch.
Inch.	Inch.	Lbs.	Lbs.	Tons.	(wts.)	(wts.)	Tons.	(wts.)	(wts.)	Tons.	(wts.)	(wts.)
1/16	1 1/16	1 1/2	1 1/2	1 1/2	3	5	2 1/2	4	7	2 1/2	4	7
1/8	1 1/8	1 3/4	1 3/4	2 1/2	4	7	2 1/2	5	8	2 1/2	5	8
3/16	1 3/16	1 5/8	1 5/8	2 7/8	5	9	3 1/2	6	10	3 1/2	6	10
1/4	1 1/4	2 1	1 9	3 3/8	6	11	3 3/8	7	12	3 3/8	7	12
5/16	1 5/16	2 1/2	2 3	4 1/2	8	13	4 1/2	8	13	4 1/2	9	15
3/8	1 3/8	2 3/4	2 3/4	4 5/8	9	15	5 1/2	10	17	5 1/2	10	17
7/16	1 7/16	3 3/8	3 1/2	5 1/2	10	17	6 1/2	12	20	6 1/2	12	20
1/2	1 1/2	3 3/4	3 3/4	6 1/2	12	20	7 1/2	14	23	7 1/2	14	23
5/8	1 5/8	4 1/4	4 0	7 0	14	23	8 0	16	26	8 0	16	26
3/4	1 3/4	4 1/2	4 4	7 7/8	15	25	8 1/2	18	29	8 1/2	18	29
7/8	1 7/8	5 3/8	4 9	8 5/8	17	28	9 1/2	20	32	9 1/2	20	32
1 1/8	2 1/8	5 9	5 5	9 0	19	32	11 0	22	36	11 0	22	36
1 1/4	2 1/4	6 6	6 0	10 5	21	35	12 0	24	40	12 0	24	40
1 3/8	2 3/8	7 1	6 6	11 5	23	38	13 1/2	26	44	13 1/2	26	44
1 1/2	2 1/2	7 1/2	7 2	12 6	25	42	14 1/2	28	48	14 1/2	28	48
1 5/8	2 5/8	8 5	7 8	13 6	27	45	15 1/2	31	52	15 1/2	31	52
1 3/4	2 3/4	9 2	8 5	14 8	29	49	17 0	34	56	17 0	34	56
1 7/8	2 7/8	9 9	9 1	15 5	31	53	18 1/2	36	60	18 1/2	36	60
2	3	10 7	9 9	17 5	34	57	19 1/2	39	66	19 1/2	39	66
2 1/8	3 1/8	11 5	10 6	18 5	37	61	21 1/2	42	70	21 1/2	42	70
2 1/4	3 1/4	12 3	11 4	19 1	39	66	22 1/2	45	76	22 1/2	45	76
2 3/8	3 3/8	13 2	12 2	21 5	42	71	24 1/2	48	81	24 1/2	48	81
2 1/2	3 1/2	14 1	13 3	22 7	45	75	26 1/2	52	86	26 1/2	52	86
2 5/8	3 5/8	15 0	13 9	24 3	48	81	27 1/2	55	92	27 1/2	55	92
2 3/4	3 3/4	16 0	14 8	25 9	51	85	29 1/2	59	98	29 1/2	59	98
2 7/8	3 7/8	17 0	15 7	27 4	54	91	31 1/2	62	104	31 1/2	62	104
3	4	18 0	16 6	29 0	58	96	33 1/2	66	110	33 1/2	66	110
3 1/8	4 1/8	19 0	17 6	30 8	61	102	35 1/2	70	117	35 1/2	70	117
3 1/4	4 1/4	21 2	19 6	34 3	68	114	39 1/2	78	130	39 1/2	78	130
3 3/8	4 3/8	22 4	20 6	36 6	72	126	41 1/2	82	137	41 1/2	82	137
3 1/2	4 1/2	23 5	21 7	37 9	75	126	43 1/2	86	144	43 1/2	86	144
3 5/8	4 5/8	26 0	24 0	42 0	84	140	48 0	96	160	48 0	96	160
3 3/4	4 3/4	28 5	26 5	45 5	91	151	52 0	105	175	52 0	105	175
3 7/8	4 7/8	31 1	28 7	50 2	100	167	57 4	114	191	57 4	114	191
4	5	34 0	31 3	54 1	109	182	62 6	125	208	62 6	125	208

AND STRENGTH (Dixon & Corbitt).

Crucible Steel.			Patent Steel.			Plough Steel			Extra Plough Steel.		
Breaking Strain.	Working Load.		Breaking Strain.	Working Load.		Breaking Strain.	Working Load.		Breaking Strain.	Working Load.	
	Pit.	Incline.		Pit.	Incline.		Pit.	Incline.		Pit.	Incline.
Tons.	cwt.	Cwts.	Tons.	cwt.	Cwts.	Tons.	cwt.	Cwts.	Tons.	cwt.	Cwts.
2.7	5	9	3.4	6	11	4.2	8	14	4.9	10	16
3.2	6	10	4.0	8	13	4.9	10	16	5.8	12	19
4.0	8	13	5.0	10	16	6.1	12	20	7.2	14	24
4.7	9	15	5.9	12	20	7.2	14	24	8.5	17	28
5.7	11	18	7.2	14	24	8.7	17	29	10.3	21	34
6.5	13	21	8.0	16	26	9.9	20	33	11.7	24	39
7.5	15	25	9.4	19	31	11.4	23	37	13.2	27	45
8.7	17	29	10.9	22	36	13.3	26	44	15.7	31	52
10.0	21	33	12.6	25	42	15.3	30	50	18.4	36	60
11.0	22	36	13.8	28	46	16.8	33	55	19.8	40	66
12.2	24	40	15.9	31	51	18.7	37	62	22.0	44	73
13.7	27	45	17.2	35	57	21.0	42	70	24.7	49	82
15.0	30	50	19.9	39	66	22.9	46	76	27.0	54	90
16.5	33	55	20.8	43	69	25.1	50	84	29.7	59	99
18.0	36	60	22.6	47	77	27.5	57	91	32.4	64	108
19.5	39	65	24.5	49	81	29.8	59	99	35.1	70	117
21.2	42	70	26.7	53	89	32.5	65	108	38.2	76	127
22.7	45	77	28.6	57	95	34.8	69	116	40.0	83	136
24.7	49	82	31.1	62	103	37.8	75	126	44.5	89	148
26.5	53	88	33.3	67	111	40.5	80	135	47.7	95	159
28.5	57	94	35.9	72	119	43.6	87	145	51.3	102	171
30.5	61	101	38.4	77	128	46.6	92	155	54.9	108	180
32.5	67	108	40.9	82	136	49.7	99	165	58.5	117	193
34.7	69	115	43.7	87	145	53.1	106	177	62.7	127	208
37.0	74	123	46.6	93	157	56.0	113	188	66.0	133	222
39.2	78	130	49.4	99	164	60.0	120	200	70.6	141	235
41.5	87	138	52.2	105	173	63.4	127	211	74.7	149	249
44.0	88	145	57.4	111	184	67.3	134	221	79.2	158	264
49.0	98	163	61.7	123	205	74.9	150	249	88.2	176	294
51.5	105	171	64.8	130	216	78.8	157	262	92.7	187	309
54.2	108	180	68.3	137	227	83	163	276	97.0	195	325
60.0	120	200	75.0	151	252	91.8	183	306	108.0	211	360
65.7	131	219	82.8	175	275	100	201	333	118.3	238	394
71.7	143	239	90.3	180	301	109.7	219	365	129.1	258	430
78.2	156	260	98.5	197	328	119.7	239	399	140.8	281	468

The next higher working load for Extra Plough Steel Rope on inclines, in Table 207, is 60 cwts., for which a 2½-inch rope is required.

The subjoined table shows the inclination of inclined ways in inches per yard, and the length for a rise of 1, corresponding to a given number of degrees of inclination; together with the resistance of gravity for each incline.

TABLE 208. INCLINATION AND RESISTANCE OF INCLINED WAYS.

(Dixon & Corbitt, &c.)

Inclination	Inclination in Inches per Yard.	Inclination.	Resistance of Gravity due to Incline.	Inclination.	Inclination in Inches per Yard.	Inclination.	Resistance of Gravity due to Incline.
Degs.	Inches	1 in	Pounds per Ton.	Degs.	Inches	1 in	Pounds per Ton.
1	0.63	37.29	39.08	19	12.39	2.90	729.27
2	1.26	28.63	78.18	20	13.10	2.74	766.12
3	1.88	19.09	117.24	21	13.82	2.60	802.74
4	2.51	14.29	156.26	22	14.54	2.47	839.12
5	3.15	11.42	195.24	23	15.27	2.35	875.23
6	3.78	9.51	234.14	24	16.02	2.24	911.09
7	4.42	8.14	272.98	25	16.78	2.14	946.66
8	5.06	7.11	311.74	26	17.56	2.05	981.94
9	5.70	6.31	350.40	27	18.34	1.96	1016.93
10	6.34	5.67	388.97	28	19.14	1.88	1051.61
11	6.99	5.14	427.41	29	19.95	1.80	1085.97
12	7.65	4.70	465.71	30	20.78	1.73	1120.00
13	8.31	4.33	503.88	31	21.62	1.66	1153.68
14	8.97	4.01	541.90	32	22.49	1.60	1187.02
15	9.64	3.73	579.75	33	23.37	1.54	1219.99
16	10.32	3.48	617.43	34	24.28	1.48	1252.58
17	11.0	3.27	654.90	35	25.20	1.42	1284.81
18	11.69	3.07	692.20				

TABLE 209.—FLAT WIRE ROPES: STRENGTH AND WEIGHT
(Dixon & Corliss)

Size.			Charcoal Iron		Bessemer or Ingot Iron.		Crucible Steel.		Patent Steel.		Plough Steel.	
			Breaking Strain.	Working Load.	Breaking Strain.	Working Load.	Breaking Strain.	Working Load.	Breaking Strain.	Working Load.	Breaking Strain.	Working Load.
Inch.	Inch.	Lbs.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
2 $\frac{1}{4}$ X $\frac{7}{16}$		9	15	20	14	28	19	38	23	46	34	72
2 $\frac{1}{2}$ X $\frac{1}{16}$		10	12	24	16	32	22	44	27	54	42	84
2 $\frac{1}{2}$ X $\frac{1}{16}$		12	14	28	19	38	27	50	32	64	49	98
2 $\frac{3}{4}$ X $\frac{1}{16}$		14	16	32	22	44	29	58	36	72	56	112
3 X $\frac{1}{16}$		16	18	36	25	51	34	68	42	84	65	130
3 $\frac{1}{2}$ X $\frac{1}{16}$		18	21	42	29	58	38	76	48	96	74	148
3 $\frac{1}{2}$ X $\frac{1}{16}$		20	23	46	32	64	43	86	54	108	83	166
3 $\frac{3}{4}$ X $\frac{1}{16}$		22	26	52	36	72	49	98	61	122	93	186
4 X $\frac{1}{16}$		25	29	58	40	80	54	108	67	134	102	204
4 $\frac{1}{2}$ X $\frac{1}{16}$		28	32	64	44	88	58	116	73	146	115	230
4 $\frac{1}{2}$ X $\frac{1}{16}$		30	35	70	48	96	64	128	81	162	124	248
4 $\frac{3}{4}$ X $\frac{1}{16}$		32	37	74	52	104	70	140	88	176	137	270
4 $\frac{3}{4}$ X $\frac{1}{16}$		34	40	80	57	114	76	152	95	190	146	292
5 X $\frac{1}{16}$		36	44	88	62	124	83	166	104	208	157	320
5 $\frac{1}{2}$ X $\frac{1}{16}$		38	48	96	67	134	89	178	112	224	172	344
5 $\frac{1}{2}$ X $\frac{1}{16}$		40	52	104	72	144	96	192	120	240	184	368
5 $\frac{3}{4}$ X $\frac{1}{16}$		42	56	112	78	156	104	208	130	260	200	400
6 X $\frac{1}{16}$		45	60	120	83	166	111	222	138	276	213	426
6 X $\frac{1}{16}$		48	64	128	90	180	120	240	150	300	228	456
3 $\frac{1}{2}$ X $\frac{7}{16}$		13	15	30	22	44	27	54	36	72	51	108
3 $\frac{1}{2}$ X $\frac{3}{8}$		16	18	36	26	52	32	64	43	86	64	128
3 $\frac{3}{4}$ X $\frac{1}{2}$		18	20	40	30	60	37	74	48	96	73	146
4 X $\frac{3}{8}$		21	24	48	34	68	43	86	56	112	85	170
4 $\frac{1}{2}$ X $\frac{3}{8}$		24	27	54	38	76	49	98	64	128	97	194
4 $\frac{1}{2}$ X $\frac{3}{8}$		27	30	60	43	86	55	110	72	144	108	216
5 X $\frac{3}{8}$		29	34	68	48	96	63	126	81	162	123	246
5 $\frac{1}{2}$ X $\frac{3}{8}$		32	38	76	53	106	70	140	89	178	135	270
5 $\frac{1}{2}$ X $\frac{3}{8}$		36	41	82	58	116	76	152	97	194	150	300
5 $\frac{3}{4}$ X $\frac{3}{8}$		39	45	90	65	130	84	168	108	216	162	324
6 X $\frac{3}{8}$		42	50	100	70	140	92	184	118	238	175	350
6 $\frac{1}{2}$ X $\frac{3}{8}$		44	54	108	76	152	99	198	126	252	187	374
6 $\frac{1}{2}$ X $\frac{3}{8}$		47	59	118	83	166	109	218	139	278	208	416
6 $\frac{3}{4}$ X $\frac{3}{8}$		50	63	126	89	178	117	234	149	298	224	448
7 X $\frac{1}{2}$		54	68	136	96	192	126	252	160	320	240	480

TABLE 213 — FLAT HEMP ROPES: WEIGHT AND STRENGTH

* (Dixon & Corbitt, &c.)

Size.	Tarred Russian.			Combined Russian and Manila		
	Weight per Fathom.	Break- ing Stress.	Working Load.	Weight per Fathom.	Break- ing Stress.	Working Load.
	Pounds.	Tons.	Cwts.	Pounds.	Tons.	Cwts.
Inches. Four Ropes.						
$3\frac{1}{2} \times 1$	10	10	20	$9\frac{1}{2}$	11	22
$4 \times 1\frac{1}{16}$	$13\frac{1}{2}$	$13\frac{1}{2}$	27	$12\frac{1}{2}$	15	30
$4\frac{1}{2} \times 1\frac{3}{16}$	17	17	34	16	19	38
$5 \times 1\frac{1}{8}$	21	21	42	$19\frac{1}{4}$	23	46
$5\frac{1}{2} \times 1\frac{1}{2}$	25	25	50	$23\frac{1}{2}$	28	56
$6 \times 1\frac{3}{8}$	30	30	60	28	33	66
$6\frac{1}{2} \times 1\frac{3}{4}$	34	34	68	32	38	76
$7 \times 1\frac{1}{2}$	38	38	76	36	43	86
$7\frac{1}{2} \times 2$	43	43	86	40	48	96
Six Ropes.						
$4 \times \frac{3}{16}$	10	10	20	$9\frac{1}{2}$	11	22
$4\frac{1}{2} \times \frac{13}{16}$	13	13	26	12	14	28
5×1	16	16	32	$14\frac{1}{2}$	17	34
$5\frac{1}{2} \times 1\frac{1}{8}$	19	19	38	16	20	40
$6 \times 1\frac{1}{4}$	22	22	44	20	24	48
$6\frac{1}{2} \times 1\frac{3}{8}$	25	25	50	$22\frac{1}{2}$	27	54
$7 \times 1\frac{1}{2}$	28	28	56	25	30	60
$7\frac{1}{2} \times 1\frac{1}{2}$	32	32	64	29	34	68
$8 \times 1\frac{3}{8}$	36	36	72	33	39	78

TABLE 214.—HEMP ROPES AND WIRE ROPES: SIZE AND WEIGHT FOR EQUAL STRENGTHS.

(J. Shaw)

I. ROUND ROPES.

Hemp.		Crucible Cast Steel		Charcoal Wire.		Strength	
Circumference.	Weight per Fathom (approximate).	Circumference.	Weight per Fathom (approximate).	Circumference.	Weight per Fathom (approximate).	Breaking Stress.	Working Load (approximate).
Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.	Tons.	Cwts.
3½	3	1½	1½	1½	2	2½	9
4	4	1¾	1¾	1¾	2½	4	15
4½	5	1½	2	2	3½	6	20
5	6½	1¾	2½	2½	4½	7½	24
5½	7½	1¾	3	2½	5½	9½	30
6	8½	2	3½	2¾	6½	11½	36
6½	10	2¼	4½	3	7½	14	45
7	12	2½	5½	3½	8½	16	52
7½	14	2¾	6	3½	10½	19	62
8	16	2¾	6½	3¾	12½	22	74
8½	18	3	7½	4	14	25	80
9	20	3½	9½	4½	16	28	95
9½	23	3½	10½	4½	18	32	105
10	26	3¾	12½	4¾	20	36	120
10½	29	4	14½	5	22	40	135
11	31	4½	15	5½	25	45	150
11½	34	4½	16	5½	28	50	160
12	37	4½	16	5¾	31	55	170
13	41	4¾	20	6	35	60	180

II. FLAT ROPES.

Size, Inches.		Size, Inches.		Size, Inches.			
3½ × 1	12	...	...	2½ ×	10	18	40
4 × 1½	17			2½ ×	12	20	45
4½ × 1½	20			2¾ ×	14	23	51
5 × 1½	24	2½ × 1½	10	3 ×	16	27	58
5½ × 1½	27	2½ × 2	12	3½ ×	18	30	60
6½ × 1½	30	2½ × 2½	14	3½ ×	20½	33	68
6½ × 2	33	3 × 2	16	3¾ ×	22½	36	78
7 × 2	36	3½ × 2½	18½	4 ×	25	39	90
7½ × 2½	39	3½ × 3	21	4½ ×	28	42	105
8 × 2½	42	3¾ × 3	22½	4½ ×	32	45	118

TABLE 215.—STEEL WIRE ROPES : BREAKING STRESS.
(J. Shaw.)

Plough Steel Wire Rope.		Hard Steel Ropes.		Iron Wire Guides, or Conducting Rods.	
Circumference.	Breaking Stress.	Circumference.	Breaking Stress.	Circumference.	Weight per Fathom.
Inches.	Tons.	Inches.	Tons.	Inches.	Pounds.
1½	12	1½	9½	2¾	13
1¾	15½	1¾	11½	3	15
2	18	2	14	3¼	18
2¼	24	2¼	17	3½	21
2½	27	2½	21	3¾	24
2¾	31½	2¾	26	4	28
3	38	3	31		
3¼	46	3¼	37		
3½	53	3½	42		
3¾	59	3¾	50		
4	68	4	55		
4¼	76	4¼	63		
4½	88	4½	71		
5	100	5	90		

Duboul's Experiments on the Strength of Ropes.

M. Duboul tested ropes and cables of white hemp and tarred hemp, Italian, Russian, and French ; of long fibre, hand spun, with from fifty to fifty-five twists to the yard ; 1½ yards of rope yarn sufficing to make one yard of cable. A selection of results is given in Table 216.

Flat tarred ropes were proved to a mean strength of from 3.43 tons to 3.75 tons per square inch, rupture taking place at the points of attachment. The extension rarely exceeded from 5 to 6 per cent.

The average ultimate tensile strength of rope was as follows:—

	Tons.	Tons.
White hemp	4.76 to 5.08	per square inch.
Tarred hemp	3.54 „ 3.81	„ „ „
White Manilla	4.44 „ 4.76	„ „ „
White aloes	2.54 „ 3.17	„ „ „
Flat ropes of tarred hemp, or Tarred Manilla	3.54 „ 3.81	„ „ „
Esparto and cocoa fibres	1.00 „ 1.25	„ „ „

M. Duboul deduced from results of practice that round ropes and cables may be worked at a stress equal to one-third of the ultimate strength ; and flat ropes at one-fourth. In ordinary practice, the proportion is often not more than from one-sixth to one-eighth.

TABLE 216.—RESULTS OF TESTS OF ROUND ROPES.
(M. Duboul)

	White Hemp		Tarred Hemp.	White Manilla.		White Aloes.	
Circumference before rupture . .	4.33	4.33	4.25	3.94	3.94	4.33	4.33
" after	3.86	3.74	3.74	3.27	3.39	3.54	3.66
Length tested	32.8	32.8	32.8	32.9	32.8	32.8	32.8
" measured for testing extension . .	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Extension	27.2	28.3	26.4	23.2	22.8	20.0	26.8
Section of the four strands	8.19	8.19	8.19	8.19	8.19	8.19	8.19
Section of the piece	1.400	1.490	1.481	1.246	1.246	1.491	1.491
Resistance	7.94	7.43	5.22	5.44	5.96	3.99	4.45
" of the four strands per square inch	9.78	9.02	6.35	6.60	7.24	4.83	5.40
" of the piece per square inch	5.27	4.95	3.49	4.32	4.76	2.67	2.98
Weight of the whole piece tested	17.4	17.6	18.7	15.0	15.2	15.0	15.4

M. Dubaut estimates that ropes and cables of galvanized charcoal-iron wire unannealed, have two-tenths of the diameter of hemp cables of equal strength; or three-tenths for annealed wire.

	Ultimate Strength per Square Inch, Section of Metal	Extension.	Elasticity.
Rope of unannealed wire	25.4 to 31.7 tons	7 to 9 %	1 to 2 %
„ annealed „	22.2 to 25.4 „	12 to 15 „	3 to 4 „

The galvanized wire tested by itself, yields 10 per cent. more resistance to rupture than in the form of rope.

Wire-ropes for mining service, of the first quality, have a ultimate strength of from 10 to 45 tons per square inch of metal section.

Cast-steel wire ropes stretch from 4 to 6 per cent. before rupture, with an elastic limit of from 2 to 3½ per cent. They bear three-fourths of the breaking stress before exhibiting any sign of failure.

TABLE 217.—STEEL WIRE ROPE, FOR STANDING RIGGING (Admiralty)

Size of Rope (Girth).	Number of Strands.	Wires in one Strand	Thick- ness of Wires.	Weight per Fathom.	Length of one Coil.	Breaking Stress (Minimum).
Inches.	Strands.	Wires.	L. W. G.	Pounds.	Fathoms.	Tons.
8	6	19	6	62	100	160
7½	6	19	7	53	100	141
7	6	19	8	46	100	123
6½	6	19	6	40	100	106
6	6	19	10	34	100	90
5½	6	19	10	28	100	76
5	6	19	12	23	100	63
4½	6	19	12	19	150	51
4	6	19	14½	15½	150	40
3½	6	7	10	11½	170	32
3¼	6	7	11	10	150	27
3	6	7	12	8	200	24
2¾	6	7	13	7	200	19
2½	6	7	13	6	200	16
2¼	6	7	14	5	200	13
2	6	7	15	4	200	10
1¾	6	7	16	3	200	8
1½	6	7	18	2	200	6
1¼	6	7	18	1½	200	3½
1	6	7	20	1	200	2½

TABLE 218.—STEEL WIRE ROPES, FOR HAWSERS AND RUNNING RIGGING.

(Admiralty.)

Size of Rope (Girth).	Number of Strands.	Wires in one Strand.	Thick-ness of Wires.	Weight per Fathom.	Length of one Coil.	Breaking Stress (Minimum).
Inches.	Strands.	Wires.	in W. G.	Pounds.	Fathoms.	Tons.
8	6	30	9	.	150	.
7	6	30	11	.	150	..
6½	6	30	12	35	150	98
6	6	30	12	31	150	84
5½	6	25	12	28	150	71
5	6	25	13	23	150	59
4½	6	12	12	15	150	39
4	6	12	13	12	240	31
3½	6	12	14	9	360	24
3¼	6	12	15	8	360	20
3	6	12	16	7	360	17
2¾	6	12	17	5½	360	14½
2½	6	12	17	4½	360	11½
2¼	6	12	18	3¾	300	9
2	6	12	19	2¾	300	7
1¾	6	12	20	2	300	5½
1½	6	12	21	1¾	300	4
1¼	6	12	22	1½	300	2¾
1	6	12	24	¾	300	1½

Resistance of Ropes to Bending Stress.

The resistance of ropes to bending stress in passing over a pulley or a barrel is expressed by the following formulas, the equivalents in English measures of Longacre's formulas —

Hemp Ropes, either White or Tarred.

$$S = .0328 T \frac{w}{D} \quad . \quad . \quad . \quad . \quad . \quad (125)$$

Iron Wire Ropes (Hemp Core)

$$S = (3.61 + .00262 T) \frac{w}{D} \quad . \quad . \quad . \quad . \quad . \quad (126)$$

Steel Wire Ropes (Hemp Core).

$$S = (6.814 + .00262 T) \frac{w}{D} \quad (127)$$

Steel Wire Ropes, rusted.

$$S = (5.412 + .00262 T) \frac{w}{D} \quad (128)$$

Steel Wire Ropes, Lubricated in Oil Bath.

$$S = (8.428 + .00172 T) \frac{w}{D} \quad (129)$$

S = resistance to bending stress ; or the total tensile stress or pull minus the resisting stress in the rope, in the advancing limb of the rope.

T = resisting stress on the rope, in the advancing limb of the rope.

w = weight of rope per fathom, in pounds.

D = diameter of pulley or barrel, in feet.

The foregoing formulas apply to ropes which are new or nearly new ; and for wire ropes of wire 3 millimetres, or about $\frac{1}{8}$ inch thick. The resistance may be reduced ultimately by wear by 20 per cent. for iron ropes, and 88 per cent. for steel ropes. The experiments were made with wire ropes of from 6 lbs. to 13 lbs. per fathom, or from .83 inch to 1.30 inch in diameter.

CHAINS AND CHAIN-CABLES.

Cables for use in the naval and merchant service are made of round iron, in lengths of 15 fathoms, with stud-links. For standing rigging and crane chain, short or unstudded links are employed.

Chains are made of puddled iron, bars of which have, or ought to have, an ultimate tensile strength of 23 tons per square inch, stretching from 20 to 25 per cent. in a length of 10 inches ; with a contraction of sectional area of from 45 to 50 per cent.

The links of chain-cables and short links generally are geometrically similar for all sizes, according to the following proportions, which are those of the links after having been submitted to the proof stress : the length of the common stud-link being 6 diameters, and the width about $3\frac{1}{2}$ diameters, whilst the length and width of the short-link are respectively about 5 diameters and $3\frac{1}{2}$ diameters.

		Stud-Link.	Short-Link.
	Diameter of iron . . .	1	1
Common Links	Length of link outside . .	6	4.9
	Width of link outside . .	3.6	3.5
	Radius of each end inside .	.58	.60
	Length of stud at crown . .	1.6	—
	Width in parts of length .	60 per cent.	71 per cent.
Enlarged Links	Diameter of iron . . .	1.1	1.1
	Length of link outside . .	6.5	5.7
	Width of link outside . .	4.0	3.8
	Radius of each end inside .	.64	.65
End Links	Diameter of iron . . .	1.2	1.2
	Length of link outside . .	6.5	6.6
	Width of link outside . .	4.0	4.1

The length of one link varies as the size or diameter, whilst the weight is as the cube of the diameter. The weight per unit of length, — say, one fathom, — varies, therefore, as the square of the diameter, and is expressed by the following formulae, in which d is the size or diameter in inches, and W is the weight per fathom in pounds:—

$$\text{(Stud-link chains)} \quad W = 53.76 d^2 \quad (130)$$

$$\text{(Short link or crane chain)} \quad W = 55 d^2 \quad (131)$$

The proof tensile strength also varies as the square of the diameter, and therefore it varies as the weight.

	Stud Link.	Short-Link.	
The actual ultimate strength of good ordinary cable, in tons . . .	$-29d^2$ to $26.7d^2$	$27.3d^2$ to $25.1d^2$	(132)

The statutory ultimate strength in tons . . .	$-27d^2$ to $25.2d^2$	$24d^2$	(133)
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The statutory proof strength in tons . . .	$-18d^2$	$12d^2$	(134)
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The safe working stress (half the proof strength) . .	$-9d^2$	$6d^2$	(135)
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It is here shown that whilst the actual ultimate strength (132) of short-links is little less than that of stud-links, the

proof stress and the safe-working stress, (134) and (135), for the short links are only two-thirds of those for the stud-links by reason of the lower elastic limit of the short links.

The Tables 219 and 220, from which the foregoing formulæ have been deduced, give the dimensions, weight, and strength of stud-link and short-link chain cables. In Table 220 for short links, there are no statutory tests for cables above $1\frac{1}{2}$ inches in diameter, but the appropriate stresses, with actual strengths for the larger sizes, calculated and supplied by Mr. T. Traill (in "*Chain Cables and Chains*") are added in the table. In the second last column are given the safe-working strengths of cables, the factor of strength averaging for stud-links a little over 3; and for short-links about $4\frac{1}{2}$.

The safe-working load in tons is approximately expressed by the following formulæ . .

$$\text{Short-link chain} \quad . \quad . \quad \frac{D^2}{10} \quad . \quad . \quad (136)$$

$$\text{Stud-link chain.} \quad . \quad . \quad \frac{D^2}{7} \quad . \quad . \quad (137)$$

in which D is the diameter of the iron in eighths of an inch. The values thus obtained are about 7 per cent. too high for the short-link chain, and about 1 per cent. too high for the stud-link chain.

The Admiralty have special proportions for iron chain rigging and crane work, for which the sizes and weights are given in Table 222. The Admiralty chain moorings are noted in Table 221, in which the sizes, weights, and proof stresses are given. They are of unstudded or open links, and these are shaped differently from the ordinary short-link being made thicker at the ends, the wearing parts. Mooring chains are in consequence heavier than short-link chains of the same sizes.

The India Office prescribe for all services, except Marine short-link chains, of which the common links are not to exceed $4\frac{1}{2}$ diameters in length, and $3\frac{1}{2}$ diameters in width. The weight and conditions of test are given in Table 223.

In the Trinity House contracts, it is specified that mooring chains, chain cables, crane and rigging chains, and appurtenances, except the stay-pins and steel pins, are to be of fibrous iron, to have a tensile stress of not less than 23 tons per square inch, with a contraction of sectional area at the fracture of not less than 40 per cent. of the original area. The cast iron of which the stay-pins are made is to have a compressive stress of not less than 52 tons per square inch.

TABLE 219.—STUD-LINK CHAIN-CABLES: DIMENSIONS, WEIGHT, AND STRENGTH.

Diameter of Iron.	Length of the Link, Outside.	Width of One Link, Outside.	Radius of End of Link, Inside.	Length of Stud at Crown	Weight of		Statutory Proof Tensile Stress, for each 15 Fathoms sepa- rately.	Statutory Strength or Break- ing Stress on Three Links in each 15 Fathoms.	Actual Breaking		Safe- Working Stress, (Half the Proof Stress).	Ultimate Strength per Square Foot of Good Ordinary Plate.
					100 Fathoms	One Fathom (Six Feet).			Good Ordinary Cable	High Breaking Stress		
Inches	Inches	Inches	Inches	Inches	Cwts.	Pounds.	Tons.	Tons	Tons.	Tons	Tons.	Tons.
$\frac{1}{16}$	2 3	1 12	1 1	1 1	9 2	11 3	3 4	5 1	5 4	5 3	1 7	18 0
$\frac{1}{8}$	3	1 12	1 1	1 1	12	13 4	4 5	6 3	7 4	7 6	2 4	18 1
$\frac{3}{16}$	3 3	2 1	1 1	1 1	15 2	17 2	5 8	8 4	9	9 4	2 8 1	18 1
$\frac{1}{4}$	3 3	2 1	1 1	1 1	18 7 5	21	7	10 5	11 2	11 9	3 1	18 2
$\frac{5}{16}$	4 4	2 1	1 1	1 1	22 7	25 4	8 5	12 4	13 6	14 5	4 1	18 3
$\frac{3}{8}$	4 4	2 1	1 1	1 1	27	30 2	10 4	15 4	16 2	17 3	5 1	18 3
$\frac{7}{16}$	4 4	2 1	1 1	1 1	31 7	35 5	11 4	17 8	19	20 3	5 9 4	18 3
$\frac{1}{2}$	5 5	3 3	1 1	1 1	36 7 5	41 2	13 4	20 6	22 4	23 6	6 4	18 3
$\frac{5}{8}$	5 5	3 3	1 1	1 1	42 2	47 2	15 8	23 7	25 4	27 4	7 9	18 4
$\frac{3}{4}$	6 6	3 3	1 1	1 1	48	53 8	18	27	29	31 1	9	18 5
1	6 6	3 3	1 1	1 1	54 2	60 7	20 8	30 4	32 4	34 9	10 15	18 4
$1 \frac{1}{8}$	6 6	4 1	1 1	1 1	60 7 5	69	22 4	34 6	36 5	39	11 3	18 3
$1 \frac{1}{4}$	7 7	4 1	1 1	1 1	67 7	75 8	25 8	38	40 5	43 3	12 4 9	18 3
$1 \frac{3}{8}$	7 7	4 1	1 1	2	76	84	28 4	42 4	44 4	47 9	14 1	18 2
$1 \frac{1}{2}$	7 7	4 1	1 1	2 3	82 4	92	31	46 5	49 4	52 4	15 4	18 2
$1 \frac{5}{8}$	8 4	4 1	1 1	2 10	90 7 5	101 6	34	51	53 8	57 5	17	18 1

TABLE 219.—STUD-LINK (CHAIN-CABLES) (continued).

Diameter of Stud Inches	Length of Link, Inches	Width of Eye Link, Inches	Radius of End of Link, Inches	Length of Stud at Crown, Inches	Weight of 100 Fathoms (one six feet)		Statutory Proof Stress, for each 15 Fathoms separ- ately.	Statutory Strength or Break in Stress on Three Links in each 15 Fathoms	Actual Breaking Stress		Safe Working Stress (Half the Proof Stress)	Ultimate or Break ing Stress per Square Inch of Good Ordinary Cable
					Pounds.	Tons.			Tons.	Tons.		
1 1/16	10 1/2	3 1/8	2 1/4	2 1/4	99.5	37 1/2	37 1/2	55 1/2	58 1/2	69.7	18.5 1/2	18.0
1 1/8	10 1/2	3 1/8	2 1/4	2 1/4	108	40.5	40.5	58 1/2	63 1/2	68	23 1/2	18.0
1 1/4	10 1/2	3 1/8	2 1/4	2 1/4	116.8	43.9	43.9	61.4	68.7	73.6	22	17.9
1 1/2	10 1/2	3 1/8	2 1/4	2 1/4	126.75	47.5	47.5	66.5	74	79.8	23 1/2	17.8
1 3/4	10 1/2	3 1/8	2 1/4	2 1/4	138.7	51.4	51.4	71 1/2	79 1/2	85.2	25 1/2	17.8
1 7/8	10 1/2	3 1/8	2 1/4	2 1/4	147	55.4	55.4	77 1/2	85 1/2	91.8	27 1/2	17.7
2	10 1/2	3 1/8	2 1/4	2 1/4	158	59.4	59.4	82 1/2	91.2	97 1/2	29 1/2	17.7
2 1/16	11 1/2	3 1/8	2 1/4	2 1/4	168.75	63.4	63.4	88 1/2	97.4	104 1/2	31 1/2	17.6
2 1/8	11 1/2	3 1/8	2 1/4	2 1/4	180	67.5	67.5	94.5	103 1/2	110 1/2	33 1/2	17.6
2 1/4	11 1/2	3 1/8	2 1/4	2 1/4	192	72	72	100.8	109.9	117 1/2	36	17.5
2 3/8	12 1/2	3 1/8	2 1/4	2 1/4	203	76.5	76.5	107.1	116.4	124 1/2	38 1/2	17.4
2 1/2	12 1/2	3 1/8	2 1/4	2 1/4	216.75	81 1/2	81 1/2	113 1/2	123 1/2	131 1/2	40 1/2	17.3
2 7/8	13 1/2	3 1/8	2 1/4	2 1/4	229	86 1/2	86 1/2	120.5	130.1	139 1/2	43	17.3
3	13 1/2	3 1/8	2 1/4	2 1/4	243	91 1/2	91 1/2	127.5	137.4	146 1/2	45 1/2	17.2
3 1/16	14 1/2	3 1/8	2 1/4	2 1/4	256	96 1/2	96 1/2	134 1/2	144 1/2	154 1/2	48 1/2	17.2
3 1/8	14 1/2	3 1/8	2 1/4	2 1/4	270.2	101 1/2	101 1/2	142.1	151 1/2	162 1/2	50 1/2	17.1
3 1/4	14 1/2	3 1/8	2 1/4	2 1/4	285	106.9	106.9	149.8	159.2	171	53 1/2	17.1
3 3/8	15 1/2	3 1/8	2 1/4	2 1/4	300	112.5	112.5	157.5	169 1/2	178 1/2	56 1/2	17.0

original area of section, with a reduction in length of not less than 10 per cent. The steel pins for retaining the joining shackle-bolt, are to be capable of bearing a tensile stress not less than 35 tons per square inch, with a contraction at the fracture of not less than 45 per cent. of the original area. Mooring and close-link crane and rigging chains are to be proved to a stress of 8.47 tons per square inch of section of the sides of the link, or 465 pounds per circular $\frac{1}{8}$ inch of section. Defective links are to be cut out and replaced. Stud-chain cables are to be proved according to the Act, as already described. Four-foot sample lengths of chain are to be tested for ultimate strength, which is not to be less than 16 tons per square inch of section of both sides of the links, or 880 pounds per circular $\frac{1}{8}$ -inch.

The $1\frac{1}{2}$ -inch mooring chain is made in lengths of 15 fathoms, with a joining shackle to each length, and a swivel for every 30 fathoms. The $1\frac{1}{2}$ inch, $1\frac{1}{4}$ inch, 1 inch, and $3\frac{3}{4}$ inch mooring chains are in lengths of from 8 fathoms to 45 fathoms. Stud-chain cables are made in lengths of $12\frac{1}{2}$ fathoms. The common links of mooring chains are 6 diameters in length, the breadth is 3.5 diameters. The ordinary end link is of iron, 1.2 diameters, $6\frac{1}{2}$ diameters in length, 4.1 in breadth.

TABLE 221.—CHAIN MOORINGS, IN TEN-FATHOM LENGTHS: OPEN OR UNSTUDDED LINKS, SIZES, WEIGHT, AND PROOF-STRESS.

(Admiralty)

Size, or Diameter of Iron at Sides of Link.	Greater Diameter at the Ends of Link	Weight of Ten Fathoms.	Proof-Stress.
Inches	Inches.	Cwts.	Tons.
$2\frac{1}{4}$	3.025	49	72
$2\frac{3}{4}$	3.162	45	79
3	3.3	50	86
$3\frac{1}{8}$	3.437	55	93
$3\frac{1}{4}$	3.575	60	101
$3\frac{1}{2}$	3.85	75	117
$3\frac{3}{4}$	4.125	87	134

Note.—The breaking stress must be not less than 1.40 times the proof stress; that is, 40 per cent. more.

TABLE 222. CHAIN-RIGGING, (CRANE CHAIN OR LINK) SIZE AND WEIGHT
(Admiralty.)

Size or Diameter of Iron	Weight of One Fathom	Size or Diameter of Iron	Weight of One Fathom	Size or Diameter of Iron	Weight of One Fathom
Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.
$\frac{1}{4}$	2	$\frac{3}{4}$	21	$1\frac{1}{8}$	70
$\frac{3}{16}$	3	$\frac{7}{8}$	25	$1\frac{1}{4}$	80
$\frac{1}{2}$	4 $\frac{1}{2}$	$1\frac{1}{8}$	30	$1\frac{3}{8}$	100
$\frac{5}{16}$	5 $\frac{1}{2}$	$\frac{1}{2}$	36	$1\frac{1}{2}$	130
$\frac{3}{8}$	6 $\frac{3}{4}$	$\frac{1}{4}$	39	$1\frac{5}{8}$	150
$\frac{7}{16}$	9 $\frac{1}{2}$	$\frac{3}{4}$	48	$1\frac{3}{4}$	170
$\frac{1}{2}$	13 $\frac{1}{4}$	$\frac{1}{2}$	53		
$\frac{3}{4}$	17	$\frac{1}{4}$	61		

TABLE 223.—SHORT LINK CHAINS: WEIGHT AND CONDITIONS OF TEST.
(India Stores Department.)

Diameter of Iron.	Weight of One Fathom.	Proof Stress.	Load on Test Piece	Elastic Test Piece 7 $\frac{1}{2}$ by 1 $\frac{1}{2}$ Inches
Inches.	Pounds.	Tons.	1 ins.	inches
$\frac{1}{4}$	1	$\frac{3}{16}$	$\frac{7}{16}$	6
$\frac{3}{16}$	2 $\frac{1}{4}$	$\frac{1}{8}$	1	7
$\frac{1}{2}$	3 $\frac{3}{4}$	$\frac{1}{4}$	$1\frac{1}{4}$	8 $\frac{1}{2}$
$\frac{5}{16}$	6	$1\frac{1}{8}$	3	9 $\frac{1}{2}$
$\frac{3}{8}$	8 $\frac{1}{2}$	$1\frac{1}{2}$	$4\frac{1}{2}$	10 $\frac{1}{2}$
$\frac{7}{16}$	11 $\frac{1}{2}$	2 $\frac{1}{4}$	$5\frac{1}{4}$	11 $\frac{1}{2}$
$\frac{1}{2}$	15	3	7	12 $\frac{1}{2}$
$\frac{5}{8}$	19	3 $\frac{3}{4}$	8 $\frac{1}{2}$	14
$\frac{3}{4}$	23 $\frac{1}{2}$	4 $\frac{1}{2}$	11 $\frac{1}{4}$	15 $\frac{1}{2}$
$\frac{7}{8}$	28 $\frac{1}{2}$	5 $\frac{1}{2}$	13 $\frac{1}{4}$	17 $\frac{1}{2}$
$\frac{1}{2}$	34	6 $\frac{3}{4}$	16 $\frac{1}{4}$	19 $\frac{1}{2}$
$\frac{1}{2}$	40	7 $\frac{3}{4}$	18 $\frac{1}{4}$	21 $\frac{1}{2}$
$\frac{1}{2}$	46	9 $\frac{1}{4}$	22	23 $\frac{1}{2}$
$\frac{1}{2}$	53	10 $\frac{1}{4}$	24 $\frac{1}{2}$	25 $\frac{1}{2}$
1	60	12	29	28 $\frac{1}{2}$
$1\frac{1}{8}$	76	15 $\frac{1}{4}$	36 $\frac{1}{4}$	32 $\frac{1}{2}$
$1\frac{1}{4}$	94	18 $\frac{1}{4}$	41 $\frac{3}{4}$	36 $\frac{1}{2}$
$1\frac{1}{2}$	114	22 $\frac{1}{4}$	51 $\frac{1}{4}$	40 $\frac{1}{2}$
$1\frac{3}{4}$	135	27	64	44 $\frac{1}{2}$

FRAMING.

Cranes.

When a crane abc , fig. 72, is loaded at c by the weight W , the stresses in the three members ab , ac , and bc , due to the load, are measured proportionally by the respective lengths of

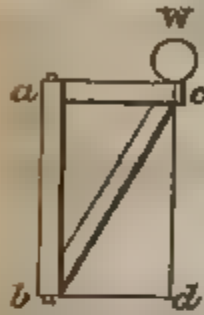


FIG. 72. Crane.

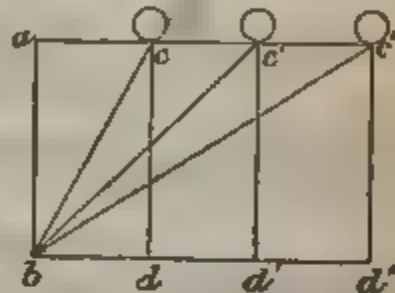


FIG. 73. —Crane.

these members; the vertical stress in the member ab , being equal to the load W . The diagonal and horizontal stresses increase with the overhang, as shown in fig. 73, by the in-

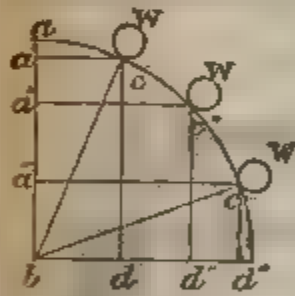


FIG. 74. Crane.

creasing lengths of the diagonal and horizontal members, bc'' , &c., and ac'' , &c.; the vertical ab being constant.

Again, the diagonal stress increases proportionally with the obliquity of the job bc'' , &c. fig. 74, taken as constant in length.

Where both the diagonal and the tie member are oblique, as bc and ac , fig. 75, the stresses in the triangular figure abc , as before, are measured proportionally by the lengths of the members, ab being the measure of the load W . The horizontal pull at a , is measured by the horizontal length ac' .



FIG. 75. —Crane.

TRUSS.

The truss or triangular frame abc , fig. 76, having equal limbs, ac , bc , supports the load W at the apex. In the parallelogram $acbe$, ce is the weight, ed is half the weight, and ea and eb are oblique compressive stresses. The horizontal tensional stress in ab

is equal to the product of the weight by the span, divided

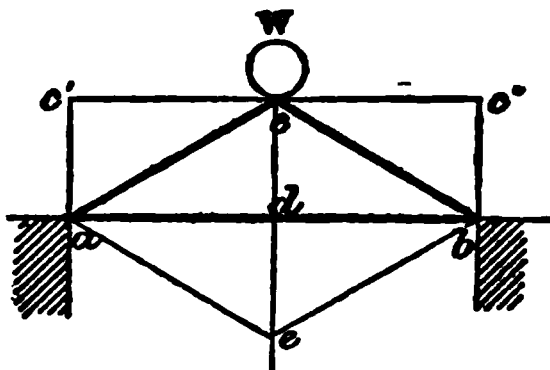


FIG. 76.—Truss.

by 4 times the rise. The horizontal thrust at the apex is equal to the tension in *ab*.

Framed Girders.

The tensional stress, or unit stress, in the extreme horizontal members *aa'* and *b'b*, fig. 77, showing a Warren girder, is equal to $\cdot 2885 W$, in which *W* is the load at the centre. The stress, whether tensional or compressive, on any bay is equal to the product of the unit-stress by the order-number of

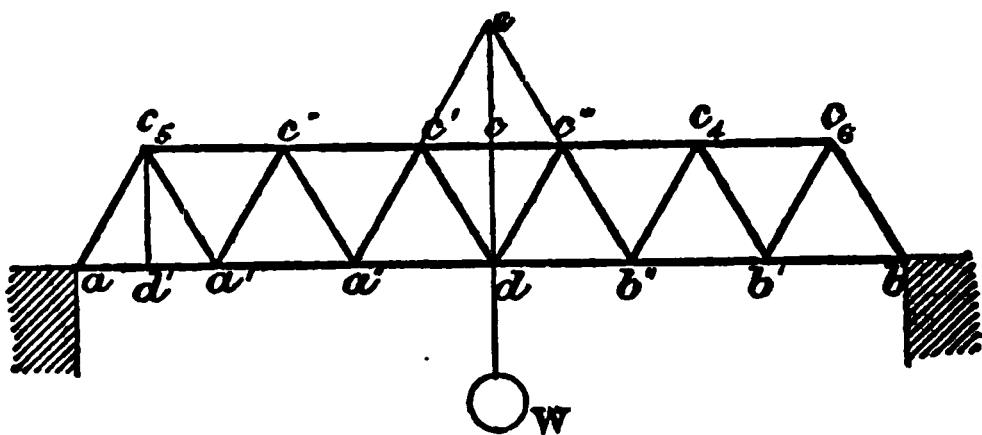


FIG. 77.—Warren Girder.

the bay ; above or below, reckoned from the extreme bay as 1, towards the middle. The stress on the central bay, also, is equal to the product of the unit-stress by $\frac{n+1}{2}$, in which *n* is the total number of bays. The stress on the middle pair of bays, tensional or compressive, is equal to the product of the unit-stress by $\frac{n-1}{2}$. In fig. 44, the stress on the central bay *e'e''*, is $1\cdot731 W$; in the central pair, it is $1\cdot443 W$. The stress in the braces is $\cdot 577 W$, or twice the unit-stress in the flange.

TRUSS ROOFS.

In the ordinary triangular roof truss, *abc*, fig 78, in which the total weight, including the load, is uniformly distributed, the tension in the horizontal member *ab*, is equal to $\frac{Wl}{8d}$, or the product of the weight by the span, divided by 8 times the rise. The horizontal thrust at the ridge *c* is equal to the tension in the horizontal tie.

When the horizontal tie, *ab*, is applied at any higher level, the tension in it is increased inversely as the depth *cd*.

In the A roof truss, fig 45, there are two trusses, each of which goes to form half the roof, and the horizontal tierod *E*. Let the span *ab* be 40 feet, the rise 10 feet, and the depth *cd* 10 feet. The rafters *ac* and *bc* are 22.5 feet long, the struts *F* are 3.33 feet long, the tension bars *C* and *D* are 11.75 feet long. The weight on the couple is 8 tons, uniformly distributed, of which 4 tons is supported on each rafter, say 1 ton at *a*, the abutment, 2 tons at *F*, and 1 ton at the ridge *c*. The

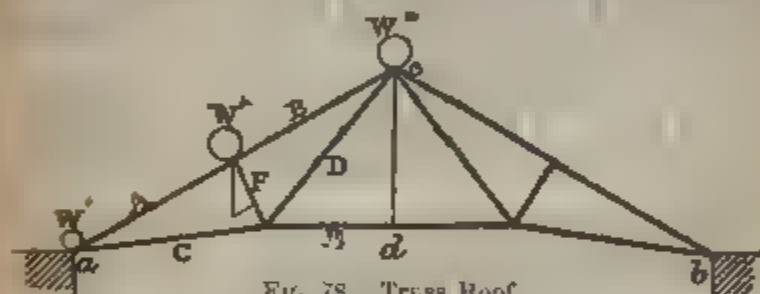


FIG. 78. TRUSS ROOF.

pressure at *F*, 2 tons, being vertical, is resolved, as indicated in the diagram, into 1.8 tons stress on *F*, and .875 tons on *A*. The stress on *F* is resolved into 3.18 tons on each of the tie-rods *C* and *D*. The tension in *E* is by formula $\frac{Wl}{8d}$, equal to

$\frac{8 \times 40}{4 \times 8} = 5$ tons, which is resolved into 4.4 tons in *C*, and .875 tons in *E*. This tension in *F* is resolved into 1.54 tons in each of *C* and *D*. Summing up the tensile stresses, there are $(3.18 + .875 + 1.54 =) 5.595$ tons in *C*; $(3.18 + 1.54 =) 4.72$ tons in *D*; and 5 tons in *E*.

HARDNESS OF METALS, ALLOYS, AND STONES.

Messrs. F. Crace Calvert and R. Johnson tested the comparative hardness of metals by the indentation made by a steel point under pressure. The steel point was about $\frac{1}{4}$ inch long; 1 millimetre or .049 inch wide at the point. Weights were added until the point entered to the extent of $3\frac{1}{4}$ millimetres or .138 inch in the course of half an hour. The Table 224 gives

the comparative hardness of several metals; and Table 225 gives the result for several alloys of copper, zinc, tin, lead, and antimony. The highest degree of hardness is that of cast iron, and it is, for the purpose of comparison, taken as 1000.

In the last column of the Table of alloys, the degree of hardness is calculated in terms of the elements separately, for simple mixtures.

The results from the alloys of copper and zinc, Table 225, No. 1, show that all the alloys having excess of copper are much harder than the metals composing them, and that increase of hardness is due to the zinc, the softer metal. But, if the zinc exceeds in proportion fifty per cent. of the alloy, the alloy becomes so brittle as to break as the point penetrates. The alloy Zn Cu, consisting of equal weights of copper and zinc, is remarkable for its hardness, which is about three times the calculated degree of hardness.

In section 4, of Table 225, may be noted the softness of the bronze with excess of tin. Also, that an increase of quantity of so malleable a metal as copper should so suddenly render the alloy brittle, until for Sn Cu¹⁰, brittleness ceases, and the hardness is nearly equal to that of wrought iron.

In section 5, Table 225, it is notable that the calculated hardness of alloys of tin and zinc, is not very different from the actual hardness: indicating a state of simple mixture of the elements.

In Table 226, is given the comparative hardness of granites and other stones according to M. Reynaud.

TABLE 224.—COMPARATIVE HARDNESS OF METALS.
(F. Grace Calvert & R. Johnson.)

Metal.	Comparative Hardness Cast Iron = 1000.
Cast Iron, Staffordshire cold-blast, gray, No. 3	1000
Steel	958
Wrought Iron (made from above cast iron)	948
Platinum	375
Copper, pure	301
Aluminium	271
Silver, pure	208
Zinc, "	183
Gold, "	167
Cadmium, pure	100
Bismuth, "	52
Tin, "	21
Lead, "	10

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS.

ALLOYS.	Proportions per cent., by Weight.		Compara- tive Hard- ness. Cast Iron = 1000.	Calculated Hardness. Cast Iron = 1000.
1. <i>Copper and Zinc.</i>				
Zn Cu ⁵ . . .	C	82.95	427	281
	Z	17.05		
Zn Cu ⁴ . . .	C	79.56	469	277
	Z	20.44		
Zn Cu ³ . . .	C	74.48	469	276
	Z	25.52		
Zn Cu ² . . .	C	66.06	473	261
	Z	33.94		
Zn Cu . . .	C	49.32	604	243
	Z	50.68		
Cu Zn ³ . . .	C	32.74	Broke	...
	Z	67.26		
Cu Zn ³ . . .	C	24.64	"	...
	Z	75.36		
Cu Zn ⁴ . . .	C	19.57	"	...
	Z	80.43		
Cu Zn ⁵ . . .	C	16.30	"	...
	Z	83.70		
2. <i>Lead & Antimony.</i>				
Pb Sb ⁵ . . .	L	24.31	Broke	...
	A	75.69		
Pb Sb ⁴ . . .	L	28.64	"	...
	A	71.36		
Pb Sb ³ . . .	L	34.86	...	...
	A	65.14		
Pb Sb ² . . .	L	44.53	...	...
	A	55.47		
Pb Sb . . .	A	38.39	...	...
	L	61.61		
Pb Sb ² . . .	A	23.68	...	...
	L	76.32		
Pb Sb ³ . . .	A	17.20	...	...
	L	82.80		
Pb Sb ⁴ . . .	A	13.48	...	...
	L	86.52		
Pb Sb ⁵ . . .	A	11.08	...	...
	L	88.92		

TABLE 225. COMPARATIVE HARDNESS OF ALLOYS (*cont.*)

Alloys.	Proportions per cent, by Weight.	Comparative Hardness, Cast Iron = 1000.	Calculated Hardness, Cast Iron = 1000.
3. Commercial Brasses			
"Large bearings"	Copper 82.05	562	259
	Tin 12.82		
	Zinc 5.13		
Mud plugs . . .	Copper 80	750	262
	Tin 10		
	Zinc 10		
Yellow brass . . .	Copper 64	520	258
	Zinc 36		
Pumps and pipes.	Copper 80	343	257
	Tin 5		
	Zinc 7.5		
	Lead 7.5		
4. Copper and Tin, (Bronze).			
Cu Sn ⁶ . . .	C 9.73	83	52
	T 90.27		
Cu Sn ⁴ . . .	C 11.86	96	60
	T 88.14		
Cu Sn ³ . . .	C 15.21	104	69
	T 84.79		
Cu Sn ² . . .	C 21.21	135	85
	T 78.79		
Cu Sn . . .	C 34.98	Broil	...
	T 65.02		
Sn Cu ² . . .	T 51.83	"	...
	C 48.17		
Sn Cu ³ . . .	T 38.29	"	...
	C 61.79		
Sn Cu ⁴ . . .	T 31.73	"	...
	C 68.27		
Sn Cu ⁵ . . .	T 27.10	"	...
	C 72.90		
Sn Cu ¹⁰ . . .	T 15.68	917	257
	C 84.32		
Sn Cu ¹⁵ . . .	T 11.03	773	271
	C 88.97		
Sn Cu ²⁰ . . .	T 8.51	640	278
	C 91.49		
Sn Cu ²⁵ . . .	T 6.83	602	281
	C 93.17		

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS (*cont.*).

ALLOYS.	Proportions per cent., by Weight.	Comparative Hardness. Cast Iron = 1000.	Calculated Hardness. Cast Iron = 1000.
<i>5. Tin and Zinc.</i>			
Zn Sn ² . . .	Z 21.65	65	61
	T 78.35		
Zn Sn . . .	Z 35.60	69	83
	T 64.40		
Sn Zn ² . . .	Z 47.49	83	110
	T 52.51		
Sn Zn ³ . . .	Z 37.57	94	123
	T 62.43		
Sn Zn ⁴ . . .	Z 31.14	105	131
	T 68.86		
Sn Zn ⁵ . . .	Z 26.57	123	142
	T 73.43		
Sn Zn ⁶ . . .	Z 15.32	121	158
	T 84.68		
<i>6 Lead and Tin.</i>			
Pb Sn ⁶ . . .	L 26.03	42	24
	T 73.97		
Pb Sn ⁷ . . .	L 30.57	41	24
	T 69.43		
Pb Sn ⁸ . . .	L 36.99	32	23
	T 63.01		
Pb Sn ⁹ . . .	L 46.82	26	20
	T 53.18		
Pb Sn . . .	L 63.78	21	20
	T 36.22		
Sn Pb ³ . . .	T 22.11	26	18
	L 77.89		
Sn Pb ⁴ . . .	T 15.01	21	17
	L 84.99		
Sn Pb ⁵ . . .	T 12.43	26	17
	L 87.57		
Sn PL ⁵ . . .	T 10.20	23	27
	L 89.80		

TABLE 226. COMPARATIVE HARDNESS OF STONES.
(Reynaud.)

Stone.	Comparative Hardness; White-veined Marble = 1.
White-veined marble	1.00
Syenite (red granite)	10.08
Green granite	9.70
Granite (dead-end)	9.30
Grey granite of the Vosges	8.02
" " Bretagne	8.56
" " Normandy	7.00
Dark grey marble	1.28
Lias limestone . . . . .	.88

The following scale of hardness is that adopted by the Technical High School at Prague. The substances are arranged in ascending order from the softest to the hardest. The test is made by drawing a conically pointed cylindrical piece of one of the metals tabulated along a polished surface of the metal to be tested. If the pointed pieces become blunt without marking the surface, the metal under test is harder than the pointed pieces employed. If neither point nor metal surface be abraded, the hardness is taken as equal. If the surface be scratched, the metal under test is taken as softer than the pointed metal —

1. Pure soft lead.
2. Pure tin.
3. Pure hard lead.
4. Pure annealed copper.
5. Fine cast copper.
6. Soft bearing metal (copper, 85, tin, 10; zinc, 5).
7. Cast iron (annealed).
8. Fibrous wrought iron.
9. Fine grained light grey cast iron.
10. Toughened cast iron melted with 10 per cent. of wrought-iron turnings).
11. Soft ingot iron, having 1 per cent. of carbon (will not harden).
12. Steel, having .45 per cent. of carbon (not hardened).
13. Steel, having .96 per cent. of carbon (not hardened).
14. Crucible cast steel, hardened and tempered blue.
15. Crucible steel, hardened and tempered violet to orange yellow.

16. Crucible steel, hardened and tempered straw-yellow.
17. Hard bearing metal (copper 83, tin 17).
18. Crucible steel, glass hard.

LABOUR OF ANIMALS.

Men.—The average net daily work of an ordinary labourer at a pump, a winch, or a crane, may be taken at 3,900 foot-pounds per minute, for 8 hours a day. But, for shorter periods, from four to five times the rate may be exerted.

Horses and Bullocks. Boulton and Watt estimated that a dray-horse could exert a power of 33,000 foot-pounds per minute, for 8 hours a day. Rennie's estimate of the average work of horses, strong and weak, was at the rate of 22,000 foot-pounds per minute for 8 hours a day.

A pair of well-fed bullocks can raise water at the rate of 8,000 foot-pounds per minute, for a morning's work of $4\frac{1}{2}$ hours.

MECHANICAL PRINCIPLES.

THE statical *moment* of a force or of a body, with respect to a given point, or axis, or plane, is expressed by the product of the weight of the body by its perpendicular distance from the point, axis, or plane.

In *levers*, the moment of the weight or resistance about the fulcrum, is equal to the moment of the power or force applied to counteract the resistance. Let P the power, W the weight or resistance, L and l respectively the lengths of the arms of the lever, taken as straight, then

the moment $P \times L$ = the moment $W \times l$,

and any one of the four quantities P , L , W , and l , can be found by a simple adaptation of the above equation, thus:—

$$P = \frac{W \times l}{L} \quad . \quad . \quad (1)$$

$$W = \frac{P \times L}{l} \quad . \quad . \quad (2)$$

$$L = \frac{W \times l}{P} \quad . \quad . \quad (3)$$

$$l = \frac{P \times L}{W} \quad . \quad . \quad (4)$$

In these equations, it is assumed that the power and resistance act on the lever at right angles to it. If the lever be bent, or if the forces act obliquely, equilibrium or equality of moments may be maintained. Draw a horizontal line through the fulcrum to meet the vertical lines through the power and the weight. The moments of the power and the weight are calculated on the horizontal lengths, and they are equal to each other.

If two or more levers are connected consecutively one to the other, as one system, and the power and the weight are applied at the two extremes, in equilibrium, the power is to the weight as the compound inverse ratio of the levers. Suppose, for instance, the arms of the levers are successively as 3 to 1, 4 to 1, and 5 to 1, the compound ratio is the product of the three ratios, or it is as $(3 \times 4 \times 5 =) 60$ to 1; and the power is to the weight as 1 to 60.

In simple *pulleys* on fixed bearings, there is no leverage, or augmentation of force; they simply transmit power, or change its direction. They act as levers having arms of equal lengths. But the pulley may be employed so as to augment the leverage, by suspending the weight to the axis of the pulley, and fixing one end of the cord, and pulling at the other end. The leverage is as 2 to 1, in this case: the weight acting at the length of the radius of the pulley from the fixed cord, and the power at the length of the diameter.

Pulleys may be combined in a pair of blocks, or sets of two or more on one axis; of which one block is fixed in position, and the other is moveable, taking the weight. The rope is usually fixed by one end to the stationary block, and is passed over the fast and moveable pulleys successively, the power being applied to the loose end. The force required at the loose end of the rope to balance the weight, irrespective of frictional and other external resistances, is equal to the quotient of the weight divided by the number of ropes by which it is carried, or the ropes proceeding from the moveable block. This number is equal to twice the number of moveable pulleys.

Conversely, to find the weight or resistance that will be balanced by a given power, irrespective of external resistances, multiply the power by the number of ropes proceeding from the moveable block.

When the fixed end of the rope is fastened to the moveable block, the divisor or multiplier is equal to twice the number of moveable pulleys plus 1.

The *wheel and axle* resemble two pulleys on one axis, *having different diameters*. If a weight be lifted by means of a rope wound over the axle or a roller on the axle, the

power being applied at the rim of the wheel, the action is like that of a lever of which the shorter arm is equal to the radius of the axle plus half the thickness of the rope, and the longer arm is equal to the radius of the wheel. The power and the weight are to each other as the radial lengths inversely, irrespective of external resistance, or they are as the diameters inversely. As with the lever, so with the wheel and axle,

the moment $P \times L$ = the moment $W \times l$,

in which P is the power or force at the circumference of the wheel, W the weight on the axle or barrel, and $L \times l$ respectively the radii of the wheel and the axle. Where,

$$P = \frac{W \times l}{L} \quad (5)$$

$$W = \frac{P \times L}{l} \quad (6)$$

On the inclined plane, if a weight be raised by a force applied parallel to the plane, the sides of the triangle formed by the plane, its base, and its height, are proportional respectively to the weight, the pressure of the weight on the plane, and the power applied.

Let l be the length of an inclined plane, and h the height, P the power, and W the weight drawn up the plane.

$$P = \frac{Wh}{l} \quad (7)$$

$$W = \frac{Pl}{h} \quad (8)$$

When the raising force is applied to the weight in a direction parallel to the base, the plane, its base, and its height are proportional respectively to the pressure of the weight on the plane, the weight, and the power applied.

The *wedge* is a pair of inclined planes united by their bases. The wedge is employed for the purpose of forcibly separating two bodies, or breaking or splitting a body: or for fastening bodies together. In the application of pressure to the head or butt-end of the wedge, to cause it to penetrate a resisting body, the power is to the resistance as the thickness of the wedge is to its length. Let t be the thickness, l the length, W the resistance, and P the power or pressure on the head of the wedge. Then,

$$P = \frac{Wt}{l} \quad (9)$$

$$W = \frac{Pl}{t} \quad (10)$$

The *screw* is an inclined plane lapped round a cylinder. The effect of a screw is reckoned in terms of the pitch or height of the plane for one revolution, and the radius of the handle or wheel by which it is turned. The power applied at the end of the radius describes, for one turn of the screw, a circle of which the diameter is twice the radius. The circumference of the circle is equal to 6.28 times the radius, and the power is to the resistance as the pitch of the screw is to 6.28 times the radius of the power, or to 3.14 times the diameter. Let p be the pitch of the screw-thread, r the radius of the lever or wheel by which the power is applied, W the weight, load, or resistance on the screw, and P the power. Then

$$6.28 Pr = Wp \quad (11)$$

$$P = \frac{Wp}{6.28r} \quad (12)$$

$$W = \frac{6.28Pr}{p} \quad (13)$$

$$p = \frac{6.28Pr}{W} \quad (14)$$

$$r = \frac{Wp}{6.28P} \quad (15)$$

If the power be applied through a wheel, the diameter of the wheel may be substituted for the radius, when half the co-efficient 3.14 is to be employed in the formulæ.

The relations are the same whether the nut be turned upon the screw, or the screw be turned within the nut.

Mechanical Centres.

There are various mechanical centres in solid or quasi-solid bodies—the centre of gravity, the centre of gyration, the centre of oscillation. The first is statical; the second and third are dynamical, inasmuch as these are only developed in bodies in motion.

Centre of Gravity.

The centre of gravity of a body is that point within the body about which the gravitation of the particles of the body is self-balanced. It is a resultant centre of action, at which the body may be supposed to be concentrated: at which it can be *freely supported or suspended* in any position in a state of *rest*. In various classes of calculation the whole weight or *mass* of a body is taken as massed at the centre of gravity *when at rest, or when in motion rectilineally*.

The centre of gravity of regular plane figures or solids—as, for instance, a straight line, a square, a parallelogram, a regular polygon, a circle, the circumference of a circle, an ellipse, a prism, a cylinder, a ring, a sphere, a spheroid, a regular solid—is the same as the geometrical centre.

The centre of gravity of a plane triangle is found by drawing a straight line from one of the angles to the middle of the opposite side, and setting off one-third of this line from the side. Or, drawing two such straight lines from two of the angles, their intersection is the centre of gravity.

The centre of gravity of a trapezium is found by drawing the diagonals, and joining the centres of each alternate pair of triangles so formed. The final intersection is the centre of gravity.

In a cone or a pyramid, the centre of gravity is in the axis, at a distance of one-fourth of its length from the base.

For an arc of a circle, multiply the bisecting radius by the chord of the arc, and divide by the length of the arc. The quotient is the distance of the centre of gravity from the centre of the circle.

For a segment of a circle, cube the chord and divide by 12 times the area of the segment. The quotient is the distance of the centre of gravity from the centre of the circle.

In a sector of a circle, the centre of gravity is two-thirds of the distance of that of an arc, from the centre of the circle. Or, multiply the radius by twice the chord of the arc, and divide by three times the length of the arc, the quotient is the distance of the centre of gravity from the centre of the circle.

In a semicircle, multiply the radius by .4244, the product is the distance of the centre of gravity from the centre of the circle.

In a solid hemisphere, the centre of gravity is at a distance of three-eighths of the radius from the centre.

For a solid spherical segment, deduct half the versed sine from the radius, and square the difference, multiply this square by the square of the versed sine and by 3.1416, and divide by the content of the segment. The quotient is the distance of the centre of gravity from the centre of the segment.

In a hemispherical surface, spherical-segment surface, or spherical-zone surface, the centre of gravity is at half the height of the axis.

In a parabola, the centre of gravity is in the axis, at a distance of three-fifths of the height from the vertex.

In a semiparabola, the centre of gravity is at the same

height as in a parabola, but it is situated at a distance from the axis, of three-eighths of the semibase.

In a parabola l , the centre of gravity is in the axis, at a distance of two-thirds of the axis from the vertex.

For two bodies, fixed one at each end of a straight bar, the common centre of gravity is in the bar, at that point which divides the distance between their respective centres of gravity in the inverse ratio of the weights. In this solution, the weight of the bar is not reckoned for. But it may be taken as a third body, and allowed for as in the following directions.

For more than two bodies connected in one system, find the common centre of gravity of two of them; and find the common centre of these two jointly with a third body, and so on to the last body of the group.

For any plane figure, the centre of gravity may be found mechanically, by suspending the figure by any point near its edge, and marking on it the direction of a plumb-line hung from that point; then suspending it from some other point near the edge, and again marking the direction of the plumb-line. The intersection of the directions is the centre of gravity.

Centre of Gyration.

The centre of gyration, revolution, or whirling, is the resultant centre of the force or work accumulated in the revolving mass; so situated that if all parts of the body were concentrated there, the work accumulated in the body, at the same angular speed would be the same as in the original body. To find the position of this point, the centre of gyration, suppose the revolving body to consist of an indefinitely great number of equal particles, as the work accumulated in each particle is proportional to the square of its velocity, and the velocity is proportional to the radius of revolution, or distance of the particle from the axis of revolution, the work in each particle is proportional to the square of its distance from the axis. Multiply the weight of each particle by the square of its distance from the axis: the product is the moment of inertia of the particle, and the sum of all the products is the moment of inertia of the whole mass. Divide the moment of inertia by the weight of the body, the quotient is the square of the radius of gyration, or of the distance of the resultant centre of gyration from the axis, and the square root of the quotient is the radius of gyration. The moment of inertia is usually represented by the symbol I . Let the total revolving weight equal w , and the radius of gyration

equal r . The relations of these quantities are expressed thus:—

$$I = wr^2 \quad . \quad . \quad . \quad (16)$$

$$\frac{I}{w} = r^2 \quad . \quad . \quad . \quad (17)$$

$$r = \sqrt{\frac{I}{w}} \quad . \quad . \quad . \quad (18)$$

Concisely expressed thus:

The moment of inertia is equal to the product of the weight by the square of the radius of gyration.

The moment of inertia divided by the weight is equal to the square of the radius of gyration.

The radius of gyration is equal to the square root of the quotient of the moment of inertia divided by the weight.

In calculating the radius of gyration, it is advisable in practice to divide the body into a considerable number of small parts—the more numerous the more nearly exact is the result. When these parts are equal, the radius of gyration may be determined by simply taking the mean of all the squares of the distances of the parts from the axis of revolution, and finding the square root of the mean square.

The radius of gyration of a straight bar, revolving about one end, is equal to the length of the bar multiplied by .5773.

That of a thin rectangular plate revolving facewise on one of its edges, is equal to the radial length of the plate multiplied by .5773.

That of a straight bar or a thin rectangular plate, revolving about its mid-length or centre, is equal to the length multiplied by .2886.

That of a straight bar or a thin rectangular plate revolving on any point between the extremities, is, generally, equal to

$\sqrt{\frac{a^3 + b^3}{3(a+b)}}$, in which a and b are the lengths of the two parts of the bar or plate. That is to say, divide the sum of the cubes of the two sub-lengths, by three times the length of the bar; the square root of the quotient is equal to the radius of gyration.

That of a circular plate, a solid wheel of uniform thickness, or a solid cylinder of any length, revolving on its axis, is equal to the geometrical radius multiplied by .7071.

That of a flat ring or hollow cylinder revolving on its axis, is equal to $\sqrt{\frac{R^2 + r^2}{2}}$, in which R and r are the outer and inner geometrical radii of the ring. That is to say, the radii

of gyration is equal to the square root of half the sum of the squares of the inner and outer radii.

That of the circumference of a circle revolving about its axis, is equal to the geometrical radius.

That of the circumference of a circle revolving about a diameter, is equal to the geometrical radius of the circle multiplied by .7071.

That of a very thin circular plate revolving about one of its diameters, is equal to half the geometrical radius of the circle.

That of a solid cylinder revolving on a diameter at mid-length, is equal to $\sqrt{\frac{l^2}{12} + \frac{r^2}{4}}$, in which l and r are the length and the geometrical radius respectively. That is to say, divide the square of the length by 12, and the square of the radius by 4, the radius of gyration is equal to the square root of the sum of the quotients.

That of a hollow cylinder revolving on a diameter at mid-length is equal to $\sqrt{\frac{l^2}{12} + \frac{R^2 + r^2}{4}}$, in which l , R , and r , are the length, and the outer and the inner geometrical radius respectively. That is to say, divide the square of the length by 12, and the sum of the squares of the inner and outer radii by 4, the radius of gyration is equal to the square root of the sum of these two quotients.

That of a very thin hollow cylinder revolving on a diameter at mid-length, is equal to $\sqrt{\frac{l^2}{12} + \frac{R^2}{2}}$, in which l and R are the length and the outer geometrical radius of the cylinder respectively. That is to say, divide the square of the length by 12, and the square of the radius by 2, the radius of gyration is equal to the square root of the sum of the quotients.

That of a solid sphere revolving about a diameter, is equal to the geometrical radius of the sphere multiplied by .6325.

That of a hollow sphere revolving about a diameter is equal to $\sqrt{\frac{2(R^5 - r^5)}{5(R^3 - r^3)}}$, in which R and r are the outer and inner geometrical radii respectively. That is to say, divide twice the difference of the fifth powers of the radii by five times the difference of the cubes of the radii; the radius of gyration is equal to the square root of the quotient.

That of the surface of a sphere, or a very thin hollow sphere revolving about a diameter, is equal to the geometrical radius of the sphere multiplied by .8165.

That of a solid cone revolving about its axis is equal to the geometrical radius of the base multiplied by .5477.

That of a solid cone revolving about its vertex is equal to $\sqrt{\frac{12l^2 + 3r^2}{20}}$, in which l is the length, and r is the geometrical radius of the base. That is to say, to 12 times the square of the length add 3 times the square of the radius: divide the sum of these by 20; the radius of gyration is equal to the square root of the quotient.

When the cone is right-angled—the radius of the base being equal to the length,—the radius of gyration is equal to the length multiplied by .8660.

That of a paraboloid revolving on the axis is equal to the geometrical radius of the base multiplied by .5773.

That of a parallelogram revolving in its own plane about one of the ends at a point midway of its breadth, is equal to

$\sqrt{\frac{4l^2 + b^2}{12}}$, in which l is the length, and b the breadth. That

is to say, to 4 times the square of the length add the square of the breadth, and divide the sum by 12; the radius of gyration is equal to the square root of the quotient.

Centre of Oscillation.

The centre of oscillation of a body vibrating about a fixed axis or point of suspension, by the action of gravity, is the resultant centre of the force or work alternately accumulated and neutralised by gravitation in the oscillating mass during each vibration. It is so situated that if all parts of the body were concentrated there, the quantity of work alternately accumulated and neutralised would continue unaltered, and the body would continue to vibrate in the same time. The centre of oscillation is in the straight line which joins the centre of gravity to the axis of oscillation. The particles of the body have velocities varying with the distance of the particles from the axis, and if the moment of inertia of the body, the method of finding which has already been explained, be divided by the weight of the body, and by the distance of the centre of gravity from the centre of suspension, the quotient will be the length of the resultant radius of oscillation, at the end of which is the centre of oscillation. Putting l and w , as before, for the moment of inertia and the weight of the body respectively, r/o for the radius of oscillation, and r/g for the radius of the centre of gravity, then

$$r/o = \frac{l}{w \times r/g} \quad (18)$$

$$\text{and } r/o \times r/g = \frac{l}{w} \quad (19)$$

But $\frac{I}{w}$ is equal to $\sqrt{\frac{I}{w}} \times \sqrt{\frac{I}{w}}$, or $(r \times r)$, the square of the radius of gyration consequently,

$$r_o^2 = r^2 + r^2 \text{ or } r_o = r\sqrt{2} \text{ (6)}$$

That is to say, the radius of oscillation is a third proportion to the radius of the centre of gravity and the radius of gyration, and finally,

$$\text{Radius of oscillation} = \frac{\text{radius}^2 \text{ of gyration}}{\text{radius of centre of gravity}} \text{ (7)}$$

In a straight line, or a uniform thin bar or cylinder, suspended by one end, oscillating about it as an axis, the centre of oscillation is at $\frac{2}{3}$ ds of the length of the rod from the axis.

In a straight line or thin bar of uniform thickness, but in which the density of its particles increase as the distance from the axis, the centre of oscillation is at $\frac{3}{4}$ ths of the length of the rod from the axis.

In a straight line or uniform thin bar, suspended at a point one-third of the length below the upper end of the bar, the centre of oscillation is at $\frac{2}{3}$ ds of the length below the axis. It is coincident with the lower end of the bar. That is to say, whether a thin bar be suspended at one end or at a point one-third of its length below the upper end, the vibration will be performed in the same time. The limit of transition of the axis is at half the length of the bar, round which point it does not oscillate at all, the centre of oscillation being indefinitely removed.

The lengths of the radius of oscillation of a few regular plane figures or thin plates, suspended by the vertex or uppermost point, are as follows:

1st. When the vibrations are flatwise, or perpendicular to the plane of the figure.

In an isosceles triangle the radius of oscillation is equal to $\frac{3}{8}$ ths of the height of the triangle.

In a circle, $\frac{5}{16}$ ths of the diameter.

In a parabola, $\frac{2}{3}$ ths of the height.

2nd. When the vibrations are edgewise, or in the plane of the figure.

In a circle the radius of oscillation is $\frac{1}{2}$ th of the diameter.

In a rectangle suspended by one angle, $\frac{1}{2}$ th of the diagonal.

In a parabola, suspended by the vertex, $\frac{1}{2}$ th of the height plus $\frac{1}{4}$ th of the parameter.

In a parabola, suspended by the middle of the base, $\frac{1}{2}$ th of the height plus $\frac{1}{2}$ th the parameter.

In a sector of a circle suspended by the centre, $\frac{1}{4}$ ths of the geometrical radius multiplied by the length of the arc, and divided by the length of the chord.

The length of the radius of oscillation of a cone is $\frac{1}{4}$ ths of the height, plus the quotient obtained by dividing the square of the radius of the base by five times the height. If a right-angled cone be suspended at its vertex, the centre of oscillation will coincide with the centre of its base, and the cone will vibrate in the same time as a simple pendulum of which the length is equal to the height of the cone.

That of a sphere suspended by a cord is $\frac{1}{4}$ ths of the square of the geometrical radius, divided by the length of the cord measured to the centre of the sphere, plus the length of the chord so taken. For example, in a sphere 8 inches in diameter, suspended by a cord or a light rod 20 inches long, as measured between the centre of suspension and the centre of the sphere, the radius of oscillation is equal to,—

$$\frac{2 \times 4^2}{5 \times 20} + 20 = .32 + 20 = 20.32 \text{ inches,}$$

or .32 inch below the centre of the sphere.

If the point of suspension be at the surface of the sphere, or at the extremity of a geometrical radius, the radius of oscillation is equal to $\frac{1}{4}$ ths of the radius, or $\frac{1}{20}$ ths of the diameter.

Centre of Percussion.

The centre of percussion of a body oscillating or vibrating about a fixed axis, is identical with the centre of oscillation, which is the point at which, if a blow is struck, the percussive action is the same as if the whole mass of the body were concentrated at the point.

The Pendulum.

A "simple pendulum" is defined as a heavy body attached to one end of a cord or a rod without weight, caused to vibrate on the centre of suspension. The time of vibration of an ordinary pendulum depends on the arc of vibration; but for arcs of vibration not 4 or 5 degrees, the time of vibration is sensibly the same for any length of arc within that limit. This uniformity of vibration is called *isochronism*.

The length or radius of oscillation of the pendulum seconds, at the level of the sea, in the latitude of 39-1393 inches. The lengths for other places

TABLE 227.—GRAVITY ; LENGTH OF SECONDS PENDULUM.

Locality.	Latitude.		Force of Gravity at the Level of the Sea : Value of g .	Length of Pendulum beating Seconds, at the Level of the Sea.
			Feet per Second.	Feet.
Equator	0	0	32·091	3·2514
Latitude 45°	45	0	32·173	3·2597
Paris	48	50	32·183	3·2609
Greenwich (London). .	51	29	32·191	3·2616
Berlin	52	30	32·194	3·2619
Dublin	53	21	32·196	3·2621
Manchester	53	29	32·196	3·2622
Edinburgh	55	57	32·203	3·2629
Aberdeen	57	9	32·206	3·2632
Pole	90	0	32·255	3·2682

The relations of time, height of fall, and velocity, are expressible as follows :—

Total time as 1, 2, 3, 4, &c.

Velocity acquired as 1, 2, 3, 4, &c.

Height of Fall as 1, 4, 9, 16, &c.

Or as 1, 2², 3², 4², &c.

Whilst the velocity is increased simply with the time, the height fallen increases as the square of the time, and as the square of the velocity. These relations are formulated in the following rules, in which,—

t = time, in seconds.

h = height fallen, in feet.

v = velocity acquired, in feet per second.

RULE 1.—To find the *velocity acquired*, given the height of fall, multiply the height by 64·4, and take the square root of the quotient.

Or, multiply the square root of the height by 8. The exact value of the coefficient is 8·025, but 8 is usually taken for ordinary calculations.

These rules are formulated thus :—

$$v = \sqrt{64\frac{1}{2} h} \quad . \quad . \quad . \quad (30)$$

$$\text{Or } v = 8\sqrt{h} \quad . \quad . \quad . \quad (31)$$

RULE 2.—To find the *velocity acquired*, given the time of fall. Multiply the time in seconds by 32·2. Or,

$$v = 32\cdot2 t \quad . \quad . \quad . \quad (32)$$

RULE 3.—To find the *height of fall*, given the velocity acquired. Square the velocity, and divide by 64·4. Or,

$$h = \frac{v^2}{64.4} \quad (33)$$

RULE 4. To find the *height of fall*, given the time. Multiply the square of the time by 16·1. Or,

$$h = 16.1 t^2 \quad (34)$$

RULE 5. To find the *height of fall*, given the velocity and the time. Multiply the velocity by the time, and divide by 2. Or,

$$h = \frac{vt}{2} \quad (35)$$

RULE 6.—To find the *time of fall*, given the velocity acquired. Divide the velocity by 32·2. Or,

$$t = \frac{v}{32.2} \quad (36)$$

RULE 7.—To find the *time of fall*, given the height. Divide the height by 16·1, and find the square root of the quotient.

Or, multiply the square root of the height by 2492.

Or, take one-fourth of the square root of the height, to find the time very nearly (within one-tenth of one per cent. of error by excess) Or,

$$t = \sqrt{\frac{h}{16.1}} \quad (37)$$

$$\text{Or, } t = 2492 \sqrt{h} \quad (38)$$

$$\text{Or, } t = \frac{1}{4} \sqrt{h} \text{ (very nearly)} \quad (39)$$

The above rules, drawn for falling bodies, are available also for the case of bodies projected freely upwards in opposition to gravity and uniformly retarded by it. The symbol v is expressive of the initial velocity with which the ascending body is propelled; h is the height to which it rises, t is the time of ascent.

The formula (33) for the height due to the velocity may be adapted for finding the head due to a velocity v , expressed in miles per hour. A speed of 1 mile per hour is equivalent to 146 feet per second, and the formula becomes by substitution, $h = \frac{1.46 v^2}{64.4}$.

By reduction, the following rule is obtained —

RULE 7.—To find the *height* due to the velocity or speed in miles per hour. Divide the square of the speed by 29·94.

$$h = \frac{v^2}{29.94} \quad (40)$$

The following table contains the times of fall, and the final velocities due to given heights of fall; Table 229 gives, conversely, the heights of fall due to given velocities; Table 230 gives the heights of fall and the final velocities due to given times of fall; Table 231 gives the heights of fall due to given speeds in miles per hour.

TABLE 228. FALLING BODIES:—HEIGHT OF FALL, AND CORRESPONDING TIME OF FALL, AND FINAL VELOCITY.

$$t = 2.402 \sqrt{h}.$$

$$v = 8.025 \sqrt{h}.$$

Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.
Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.
.01	.025	.803	1.4	.295	9.50	4.5	.529	17.03
.02	.035	1.14	1.5	.305	9.83	4.6	.534	17.21
.03	.043	1.39	1.6	.315	10.15	4.7	.540	17.40
.04	.050	1.61	1.7	.325	10.46	4.8	.546	17.58
.05	.056	1.80	1.8	.334	10.77	4.9	.552	17.78
.06	.061	1.97	1.9	.344	11.06	5.0	.557	17.99
.07	.066	2.12	2.0	.353	11.35	5.25	.571	18.41
.08	.071	2.27	2.1	.361	11.63	5.5	.585	18.82
.09	.075	2.41	2.2	.370	11.90	5.75	.598	19.24
1	.079	2.54	2.3	.378	12.17	6.0	.611	19.66
.15	.097	3.11	2.4	.386	12.43	6.25	.623	20.07
.2	.112	3.59	2.5	.394	12.69	6.5	.635	20.46
.25	.125	4.01	2.6	.402	12.94	6.75	.647	20.85
.3	.137	4.40	2.7	.410	13.19	7.0	.659	21.23
.35	.147	4.75	2.8	.417	13.43	7.25	.672	21.61
.4	.158	5.07	2.9	.424	13.67	7.5	.683	21.97
.45	.167	5.38	3.0	.432	13.90	7.75	.694	22.33
.5	.176	5.68	3.1	.439	14.13	8.0	.705	22.69
.55	.185	5.95	3.2	.446	14.36	8.25	.716	23.05
.6	.193	6.22	3.3	.453	14.58	8.5	.727	23.40
.65	.201	6.47	3.4	.459	14.80	8.75	.737	23.74
.7	.209	6.71	3.5	.466	15.01	9.0	.746	24.07
.75	.216	6.95	3.6	.473	15.22	9.25	.757	24.40
.8	.223	7.18	3.7	.480	15.43	9.5	.768	24.73
.85	.230	7.40	3.8	.486	15.64	9.75	.778	25.06
.9	.236	7.61	3.9	.492	15.85	10	.788	25.38
.95	.243	7.82	4.0	.498	16.05	10.5	.808	26.01
1.0	.249	8.03	4.1	.505	16.25	11	.827	26.62
1.1	.261	8.42	4.2	.511	16.45	11.5	.845	27.22
1.2	.273	8.79	4.3	.517	16.64	12	.863	27.80
1.3	.284	9.15	4.4	.523	16.84	12.5	.881	28.37

TABLE 228. -FALL, TIME, AND VELOCITY (continued).

Height of Fall.	Time of Fall.	Velocity ac- quired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity ac- quired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity ac- quired in Feet per Second.
Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.
13	809	28.03	43	1.634	52.62	160	3.152	101.5
13.5	916	29.49	44	1.653	53.23	170	3.250	104.6
14	933	30.03	45	1.672	53.83	180	3.344	107.9
14.5	943	30.56	46	1.690	54.43	190	3.435	110.6
15	965	31.08	47	1.709	55.02	200	3.525	113.5
15.5	981	31.59	48	1.727	55.60	225	3.738	120.4
16	997	32.00	49	1.745	56.17	250	3.941	126.9
16.1	1.000	32.20	50	1.762	56.74	275	4.133	133.1
16.5	1.013	32.60	52	1.797	57.87	300	4.317	139.0
17	1.028	33.09	54	1.831	58.97	325	4.493	144.7
17.5	1.033	33.57	56	1.865	60.05	350	4.663	150.1
18	1.057	34.05	58	1.898	61.12	375	4.826	155.4
18.5	1.072	34.52	60	1.930	62.16	400	4.984	160.5
19	1.086	34.98	62	1.962	63.19	425	5.138	165.4
19.5	1.101	35.44	64	1.994	64.20	450	5.287	170.2
20	1.115	35.89	66	2.025	65.20	475	5.432	174.9
21	1.141	36.77	68	2.055	66.18	500	5.573	179.9
22	1.167	37.64	70	2.086	67.14	550	5.845	188.2
23	1.194	38.49	72	2.115	68.09	600	6.105	196.6
24	1.221	39.31	74	2.144	69.03	650	6.354	204.6
25	1.240	40.12	76	2.173	69.96	700	6.594	212.3
26	1.271	40.92	78	2.201	70.87	750	6.825	219.8
27	1.295	41.70	80	2.229	71.78	800	7.049	226.9
28	1.319	42.47	82	2.257	72.67	850	7.266	234.0
29	1.342	43.22	84	2.284	73.55	900	7.477	240.7
30	1.365	43.95	86	2.311	74.42	950	7.681	247.3
31	1.388	44.68	88	2.338	75.28	1000	7.881	253.8
32	1.410	45.39	90	2.364	76.13	1500	9.652	310.8
33	1.432	46.10	92	2.390	76.97	2000	11.415	358.9
34	1.453	46.79	94	2.416	77.81	2500	12.46	401.2
35	1.474	47.47	96	2.442	78.63	3000	13.65	439.5
36	1.495	48.15	98	2.467	79.45	3500	14.74	474.7
37	1.516	48.81	100	2.492	80.25	4000	15.76	507.5
38	1.536	49.47	110	2.614	84.17	4500	16.72	538.3
39	1.556	50.11	120	2.730	87.91	5000	17.62	567.4
40	1.576	50.75	130	2.842	91.59	7500	21.58	695.9
41	1.596	51.38	140	2.949	94.95	10000	24.92	802.5
42	1.615	52.01	150	3.052	98.28			

during which an accelerating force is applied to the body, supposing that the body is started from a state of rest, v the final velocity acquired; s the space in feet traversed by the body during the time—the equivalent of the height in the rule for gravity; f the accelerating force in pounds; w the weight of the body in pounds. The velocity acquired is directly as the accelerating force, and inversely as the weight of the body.

Rules for Accelerated Motion.

RULE 1.—To find *the final velocity*, given the weight, the force, and the space. Multiply the force by the space, and divide by the weight; find the square root of the quotient, and multiply by 8. Or,

$$v = 8 \sqrt{\frac{fs}{w}} \quad . \quad . \quad . \quad (42)$$

RULE 2.—To find *the final velocity*, given the weight, the force, and the time. Multiply the force by the time, and by 32.2, and divide by the weight. Or,

$$v = \frac{32.2 ft}{w} \quad . \quad . \quad . \quad (43)$$

RULE 3.—To find *the force*, given the weight, the final velocity, and the space. Multiply the weight by the square of the final velocity, and divide by the space, and by 64.4. Or,

$$f = \frac{wv^2}{64.4s} \quad . \quad . \quad . \quad (44)$$

RULE 4.—To find *the force*, given the weight, the final velocity, and the time. Multiply the weight by the velocity, and divide by the time, and by 32.2. Or,

$$f = \frac{wv}{32.2t} \quad . \quad . \quad . \quad (45)$$

RULE 5.—To find *the weight*, given the force, the velocity, and the space. Multiply the force by the space, and by 64.4, and divide by the square of the velocity. Or,

$$w = \frac{64.4fs}{v^2} \quad . \quad . \quad . \quad (46)$$

RULE 6.—To find *the space*, given the weight, the final velocity, and the force. Multiply the weight by the square of the velocity, and divide by the force, and by 64.4. Or,

$$s = \frac{wv^2}{64.4f} \quad . \quad . \quad . \quad (47)$$

RULE 7. To find *the space*, given the weight, the force, and the time. Multiply the force by the square of the time, and by 16.1, and divide by the weight. Or,

$$s = \frac{16.1 ft^2}{w} \quad (47)$$

RULE 8.—To find *the space*, given the velocity and the time. Multiply the velocity by the time, and divide by 2.

$$s = \frac{vt}{2} \quad (48)$$

RULE 9. To find *the time*, given the weight, the force, and the final velocity. Multiply the weight by the velocity, and divide by the force, and by 32.2. Or,

$$t = \frac{wv}{32.2f} \quad (49)$$

RULE 10.—To find *the time*, given the weight, the force, and the space. Multiply the weight by the space, and divide by the force, find the square root of the quotient, and divide by 4. Or,

$$t = 4 \sqrt{\frac{ws}{f}} \quad (50)$$

The foregoing formulae are available for calculating questions of retarded motion; v being the initial velocity, f the retarding force, w the weight of the body, s the space in which the motion is reduced to nothing, and t the time of retardation.

RULE 11.—To find the *accelerating or retarding force* in a body which is in motion at the beginning and end of the space traversed, when the space is given, and also the velocities at the beginning and the end of the space. Divide the difference of the squares of the velocities by the space and by 64.4, and multiply by the weight. The product is the accelerating or retarding force, according as the less or the greater velocity is the initial velocity. Or,

$$f = w \left(\frac{v^2 - v'^2}{64.4s} \right) \quad (51)$$

Note—When the weight and the force are in simple relation to each other, expressible by a simple fraction, the terms of the fraction may be substituted for w and $1/f$ in the formulae (41), (42), (46), (47), (49), (50), and calculation simplified.

Descent of Bodies on Inclined Planes

The descent of a body on an inclined plane by the gravitation of the body, is a case of an accelerating force less,

that of gravity on a vertically falling body ; to be solved by the aid of the general formulas for accelerating forces. The accelerating force of gravitation on an inclined plane is to the direct force of gravity in the ratio of the height of the plane to the length of the plane ; and it is therefore inversely proportional to the length of the plane, when the height is the same. The accelerating force r is determined by multiplying the weight of the descending body by the height of the plane and dividing the product by the length of the plane. For instance, a body weighing 100 lbs., on an inclined plane 1000 feet long and 20 feet high, is controlled by an accelerating force of $(100) \times \frac{20}{1000} = 100 \times \frac{1}{50} = 2$ pounds. But, inasmuch as the accelerating force acts through a space, or length of incline, proportionally longer as the force is less, the time of descent is also proportionally longer, and the final velocity acquired at the foot of the incline is equal to that due to the vertical height for a falling body. These relations are deduced without allowance for external resistances.

To adjust formula (50) for finding the time of free descent of an inclined plane :— w and f being in proportion to l , the length of the plane and h the height of it, these may be substituted for w and f in the formula, and $t = \frac{1}{2} \sqrt{\frac{108}{f}}$ becomes

$$t = \frac{1}{2} \sqrt{\frac{l^2}{h}} ; \text{ and, as } s=l, t = \frac{1}{2} \sqrt{\frac{s^2}{h}} ; \text{ or, finally,}$$

$$t = \frac{l}{4\sqrt{h}} \quad \quad \quad (52)$$

RULE 1.—To find the *time* of descent, given the length and the height of the inclined plane. Divide the length of the plane by 4 times the square root of the height of the plane.

Central Forces.

When a body revolves about an axis or centre, it is subject to centrifugal force, by which it is urged to fly from the centre, and to centripetal force, the reactive force by which the centrifugal force is balanced, and by which the body is constrained to move in a circular path. These are known as central forces.

Central force varies as the square of the speed of revolution, whether in terms of the linear or circumferential velocity, or of the angular speed in revolutions per unit time.

It varies as the radius of the circle of revolution.
It varies as the mass or weight of the revolving body.

Let —

w = the weight of the revolving body, in pounds.

$\frac{w}{g} = \frac{w}{32.2}$ the mass of the body, g representing gravity.

v = the linear or circumferential velocity in feet per second

ω = the angular velocity, or revolutions per second.

f = the centrifugal force in pounds.

r = the radius of gyration of the revolving body, in feet.

Rules for Centrifugal Force in terms of Circumferential Velocity.

RULE 1.—To find the *centrifugal force* given the weight, the linear velocity, and the radius of gyration. Multiply the weight by the square of the linear velocity, and divide by 32.2 times the radius of gyration. Or,

$$f = \frac{wv^2}{32.2r} \quad (53)$$

RULE 2. To find the *linear velocity*, when the weight, the centrifugal force, and the radius of gyration are given. Multiply the centrifugal force by the radius of gyration, and by 32.2, and divide by the weight; take the square root of the quotient. Or,

$$v = \sqrt{\frac{32.2fr}{w}} \quad (54)$$

RULE 3.—To find the *weight*, when the centrifugal force, the linear velocity, and the radius of gyration are given. Multiply the centrifugal force by the radius of gyration, and by 32.2, and divide by the square of the velocity. Or,

$$w = \frac{32.2fr}{v^2} \quad (55)$$

RULE 4.—To find the *radius of gyration*, when the weight, the linear velocity, and the centrifugal force are given. Multiply the weight by the square of the velocity, and divide by the centrifugal force, and by 32.2. Or,

$$r = \frac{wv^2}{32.2f} \quad (56)$$

Rules for Centrifugal Force in terms of Angular Velocity.

The linear velocity v is equal to the angular velocity, ω , multiplied by the radius of gyration and by 6.2832 (twice 3.1416). Or,

$$v = 6.2832r\omega$$

By substitution, in equation (53), and reduction, formula (54) is produced.

RULE 5. To find *the centrifugal force*, when the weight, the angular velocity, and the radius of gyration are given. Multiply the weight by the square of the angular velocity and by the radius of gyration, and by 1.226. Or,

$$f = 1.226 w r_1^2 \omega^2 \quad (55)$$

RULE 6. To find *the angular velocity*, when the weight, the centrifugal force, and the radius of gyration are given. Multiply the weight by the radius of gyration, and by 1.226; divide the centrifugal force by the product so produced; and take the square root of the quotient. Or,

$$\omega = \sqrt{\frac{f}{1.226 w r_1^2}} \quad (56)$$

RULE 7.—To find *the weight*, when the centrifugal force, the angular velocity, and the radius of gyration are given. Multiply the square of the angular velocity by the radius of gyration, and by 1.226; divide the centrifugal by the product. Or,

$$w = \frac{f}{1.226 r_1^2 \omega^2} \quad (57)$$

RULE 8.—To find *the radius of gyration*, when the weight, the angular velocity, and the centrifugal force are given. Multiply the weight by the square of the angular velocity, and by 1.226; and divide the centrifugal force by the product. Or,

$$r_1 = \sqrt{\frac{f}{1.226 w \omega^2}} \quad (58)$$

Work.

The English unit of work is one foot-pound.

The French unit is one kilogrammetre.

One kilogrammetre is equal to 7.233 foot-pounds.

One foot pound is equal to .1382 kilogrammetre.

One horse power is equal to work done at the rate of 33,000 pounds lifted one foot high, or 33,000 foot-pounds, per minute; or to 550 foot-pounds per second; or to $33,000 \times 60 = 1,980,000$ foot-pounds per hour—nearly 2 millions.

One cheval-vapeur, or cheval (French horse-power) is equal to 75 kilogrammetres, or 542.5 foot-pounds, per second.

One cheval is equal to .9863 horse-power.

One horse-power is equal to 1.0139 chevaux.

One kilogramme per cheval is equal to 2.235 pounds per horse-power.

One pound per horse-power is equal to .447 kilogramme per cheval.

If the work of a horse-power, expressed in foot-pounds, be divided by 772, the quotient is the equivalent expression of horse power in heat-units, or, $(33\ 000 \div 772 =) 42\frac{3}{4}$ heat-units per minute.

The work, known also as *vis viva*, done by gravity on a falling body is equal to the weight of the body multiplied by the height of the fall: the evidence of which is the velocity of motion acquired by the body.

The quantity of work stored in a body in motion is equal to the work which would be accumulated in it by gravity in falling from such a height as would suffice to generate the same velocity of motion. Consequently, the formulas proper for the action of gravity are applicable for calculations affecting bodies in motion, and the product of the height due to the velocity by the weight of the body, is expressive of the work stored in the body.

The height due to the velocity is equal to the square of the velocity divided by 644, according to formula (33), page 431, and as tabulate 1, page 434, and

$$U = \frac{wr^2}{644} \quad (62)$$

$$\text{or } U = w \times h \quad (63)$$

U — the work accumulated in the body, in foot-pounds,

w — the weight of the body in pounds,

r — the velocity of the body in feet per second,

r_1 — the angular velocity of a revolving body, in revolutions per second.

r_m — the same in revolutions per minute.

h — the height due to the velocity, in feet.

r — the radius of gyration, in feet.

RULE 1 — To find the *work stored* in a moving body, given the weight of the body and the velocity. Multiply the weight of the body by the square of the velocity, and divide by 644.

RULE 2. To find the *work stored* in a moving body, given the weight of the body, and the height due to the velocity. Multiply the weight by the height.

The work stored in a revolving body is calculated by either of the above rules, when linear velocity is given. But when the angular velocity is given, the equivalent to the linear velocity is found by substituting the expression $6.2832r_1r_2$

already deduced, page 439, for v in the formula (1), and reducing, thus:—

$$U = 613 \, w r_1^2 v^2 \quad (64)$$

RULE 3.—To find the *work stored* in a revolving body, give the weight of the body, the angular velocity in revolutions per second, and the radius of gyration. Multiply the weight by the square of the angular velocity, and by the square of the radius of gyration, and by 613.

When the angular velocity is given as the number of revolutions per minute, it is either to be divided by 60, before being brought into calculation, in accordance with the foregoing rule; or the expression $\frac{6.2832 \, n^2}{60}$ is to be substituted

for v in the formula (1), when the expression becomes,

$$U = \frac{w}{64.4} \times \left(\frac{6.2832 \, n^2}{60} r_1^2 \right)^2 \text{ or reducing:—}$$

$$U = 00017 \, w r_1^2 n^4 \quad (65)$$

$$\text{or } U = \frac{w r_1^2 n^4}{5868} \quad (66)$$

RULE 4.—To find the *work stored* in a revolving body, give the weight of the body, the angular velocity in revolutions per minute, and the radius of gyration. Multiply the weight by the square of the angular velocity, by the square of the radius of gyration, and by .00017.

RULE 5. For the same purpose, proceed as in rule 4, except to divide by 5868, instead of multiplying by .00017.

The work done by percussive force is simply measurable by the product of the weight of the colliding mass, and the height due to the velocity of the moment of impact plus the space moved through by the colliding mass after striking. Supposing that the blow be delivered fairly, without causing vibratory action, the work of resistance is equal to the work of impact. In the driving of a wedge, for instance, the product of the advance of the wedge by the resistance, cohesive and frictional, is equal to the work stored in the striking body. In the driving of a pile, similarly, the product of the frictional resistance by the advance of the pile under the blow of a ram is equal to the work stored in the ram. Of course, the stored work may to some extent be dissipated in vibratory action, leaving but a part of the stored work for useful performance.

MILL GEARING, SHAFTING, &c.

Driving Belts.

The ultimate tensile strength of leather belts of good quality, about $\frac{1}{2}$ inch thick, is about 1,000 pounds per inch of width. That of ordinary belts is about 750 pounds per inch of width. At laced junctions of ends of belts, the ultimate tensile strength is only about 200 pounds per inch of width. Taking Briggs and Towne's data, and assuming one third of 200 pounds, or 66 $\frac{2}{3}$ pounds per inch wide, as the maximum working stress, the Table 232 gives the driving power of leather belts.

TABLE 232. DRIVING POWER OF LEATHER BELTS,
22 INCH THICK.
(Clark's Manual.)

Area of Contact	Maximum Working Stress transmitted per Inch Wide	Power transmitted per Inch Wide			Sum of the Tensions on both Sides of a Belt per Inch Wide	Resultant Pressure on the Journals per Inch Width of Belt
		At One Foot per Second, Velocity of Belt	Per Foot of Diameter of Pulley and per Turn per Minute	Ft.-lbs.		
Degrees	Pounds.	H P	H P	Ft.-lbs.	Pounds.	Pounds.
90	32.33	.055	.00308	102	101.00	71.42
100	34.80	.063	.00331	109	.08.53	75.47
110	37.07	.067	.00353	116	.06.26	78.85
120	39.18	.071	.00373	123	.04.15	81.53
135	42.06	.076	.00400	132	.01.27	84.32
150	44.64	.081	.00427	140	.88.69	85.67
180	49.01	.089	.00467	154	.84.32	84.32
210	52.12	.095	.00500	165	.80.81	78.05
240	53.33	1.00	.00527	174	.78.00	67.59
270	57.58	1.05	.00548	181	.75.75	59.56

The Table 233 of the horse-power of belting is calculated for pulleys of nearly equal diameters, or which are well apart, allowing the belt to lap half round the smaller pulley.

Where the arc of contact is sensibly less than a semicircle, the tabular power transmitted is to be reduced in the same proportion.

The Table 233 is based on an allowance of 840 feet per minute travel of belting 1 inch width per horse-power; equivalent to about 41 pounds tension per 1 inch width of belt.

TABLE 233. —DRIVING POWER OF LEATHER BELTS. (P. A. Halsey.)

Diameter of Pulley	Horse Power Transmitted by each Inch Width of Single Belt,										
	Revolutions of the Pulley per Minute.										
	50	60	70	80	90	100	110	125	150	175	200
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
12	.25	.24	.28	.32	.35	.39	.49	.69	.79	.98	1.15
14	.28	.28	.32	.37	.41	.46	.57	.80	.92	1.14	1.38
16	.26	.32	.37	.42	.47	.53	.66	.92	1.05	1.31	1.58
18	.30	.35	.41	.47	.53	.59	.74	1.04	1.18	1.48	1.77
20	.33	.39	.45	.52	.59	.65	.82	1.14	1.31	1.64	1.96
24	.39	.47	.55	.63	.71	.79	.98	1.38	1.58	1.97	2.36
28	.43	.55	.64	.73	.83	.92	1.15	1.61	1.84	2.29	2.75
32	.52	.63	.73	.84	.94	1.05	1.31	1.84	2.13	2.68	3.19
36	.59	.71	.83	.95	1.05	1.18	1.48	2.06	2.36	2.95	3.57
40	.65	.79	.92	1.04	1.18	1.31	1.64	2.20	2.62	3.27	3.94
44	.72	.87	1.01	1.15	1.30	1.45	1.80	2.53	2.89	3.60	4.34
48	.77	.94	1.10	1.26	1.42	1.57	1.95	2.75	3.15	3.93	4.72
52	.89	1.06	1.24	1.42	1.59	1.77	2.22	3.10	3.55	4.43	5.31
56	.98	1.18	1.38	1.57	1.77	1.96	2.46	3.44	3.93	4.91	5.90
60	1.08	1.30	1.52	1.73	1.95	2.17	2.71	3.79	4.33	5.41	6.50
64	1.18	1.42	1.65	1.89	2.13	2.36	2.95	4.13	4.72	5.90	7.10
68	1.28	1.53	1.79	2.04	2.30	2.56	3.20	4.48	5.11	6.40	7.68
72	1.38	1.65	1.93	2.21	2.48	2.75	3.44	4.81	5.51	6.89	8.28
76	1.48	1.77	2.07	2.36	2.66	2.96	3.68	5.18	5.90	7.38	8.85
80	1.57	1.89	2.21	2.53	2.84	3.15	3.95	5.54	6.31	7.89	9.45

Rules for Speed of Belt-Pulleys.

To find the diameter of the driving pulley. Multiply the diameter of the driven pulley by the speed, or the number of revolutions it is to make per minute, and divide the product by the revolutions of the driving pulley per minute. The quotient is the diameter of the driver.

To find the diameter of the driven pulley. Multiply the diameter of the driving pulley by its speed, and divide the product by the speed of the driven pulley. The quotient is the diameter of the driven pulley.

To find the speed of the driven pulley. Multiply the diameter of the driving pulley by its speed; and divide the product by the diameter of the driven pulley. The quotient is the speed of the driven pulley.

Weight of Belt-Pulleys (Clark's Manual).

Pulleys of from 1 foot to 4 feet in diameter, turned and finished; Midland district

$$W = 7d - 1.75 \quad (1)$$

W = weight of pulley in pounds per inch wide

d = diameter, in feet.

This formula is probably applicable for pulleys of from 10 inches to 10 feet in diameter.

Pulleys of from 1 foot to 7 feet in diameter, turned and finished, London district —

$$\text{Not exceeding 2 feet in diameter } W = 3d^2 - 6.25d + 2.5 \quad (2)$$

$$2 \text{ feet and upwards } \quad \quad \quad W = 11.625d - 9.25 \quad (3)$$

TABLE 234.—WEIGHT OF ROUND WROUGHT-IRON SHAFTING.

Diameter of Shaft	Weight per Lineal Foot.	Diameter of Shaft.	Weight per Lineal Foot.	Diameter of Shaft.	Weight per Lineal Foot.	Diameter of Shaft.	Weight per Lineal Foot.
Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.
1	2.62	2½	19.8	5½	79.2	11	317
1¼	4.06	3	23.6	5¾	86.6	12	377
1½	5.89	3½	27.7	6	94.2	13	398
1¾	6.91	3¾	32.1	6½	111	14	462
1½	8.02	3¾	33.5	7	128	15	530
1¾	9.20	4	41.9	7½	147	16	670
2	10.5	4½	47.3	8	168	17	759
2¼	11.8	4½	53.0	8½	189	18	848
2½	13.3	4¾	59.1	9	212	19	945
2¾	14.8	5	65.5	9½	236	20	1046
2½	16.4	5½	72.2	10	262		

Note. To find the weight of steel shafting, multiply the tabular by 1.02.

TABLE 235.—HORSE-POWER OF SHAFTING.

Diameter of the Shaft.	Speed or Revolutions per Minute.									
	50	60	70	80	90	100	125	150	175	200
Horse-Power transmitted by the Shaft.										
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1	.40	.48	.56	.64	.72	.80	1.00	1.20	1.40	1.60
1 1/4	.78	.94	1.09	1.25	1.40	1.56	1.95	2.34	2.73	3.12
1 1/2	1.35	1.62	1.89	2.16	2.43	2.70	2.87	4.05	4.72	5.40
1 3/4	1.72	2.06	2.41	2.75	3.10	3.44	4.30	5.16	6.02	6.88
1 7/8	2.14	2.57	3.00	3.43	3.86	4.29	5.36	6.48	7.50	8.58
2	2.64	3.17	3.70	4.23	4.76	5.27	6.59	7.91	9.23	10.55
2 1/4	3.20	3.84	4.48	5.12	5.76	6.40	8.00	9.60	11.20	12.80
2 1/2	3.83	4.60	5.37	6.14	6.91	7.67	9.58	11.50	13.42	15.33
2 3/4	4.55	5.46	6.37	7.28	8.19	9.11	11.39	13.66	15.94	18.22
2 7/8	5.36	6.43	7.50	8.57	9.64	10.72	13.40	16.08	18.76	21.44
3	6.25	7.50	8.75	10.00	11.25	12.50	15.62	18.75	21.87	25.00
3 1/4	8.33	10.00	11.67	13.34	15.01	16.67	20.83	25.00	29.17	33.33
3 1/2	10.80	12.96	15.12	17.28	19.44	21.60	27.00	32.40	37.80	43.20
3 3/4	13.73	16.48	19.23	21.98	24.73	27.46	34.33	41.19	48.05	54.93
3 7/8	17.15	20.58	24.01	27.44	30.87	34.30	42.88	51.45	60.03	68.60
4	21.09	25.31	29.53	33.75	37.97	42.17	52.71	63.25	73.79	84.33
4 1/4	25.60	30.72	35.84	40.96	46.08	51.20	64.00	76.80	89.60	102.40
4 1/2	30.71	36.85	42.99	49.13	55.27	61.41	76.76	92.12	107.47	122.82
4 3/4	36.45	43.74	51.03	58.32	65.61	72.90	91.13	109.35	127.58	145.80
4 7/8	42.87	51.44	60.01	68.58	77.15	85.74	107.17	128.61	150.04	171.47
5	50.00	60.00	70.00	80.00	90.00	100.00	125.00	150.00	175.00	200.00
5 1/4	57.88	69.45	81.02	92.59	104.16	115.74	144.68	173.60	202.54	231.47
5 1/2	66.55	79.86	93.17	106.48	119.79	133.12	166.89	199.68	233.96	266.74
5 3/4	76.04	91.25	106.46	121.67	136.88	152.08	190.10	228.12	266.14	304.16
6	86.40	103.68	120.96	138.24	155.52	172.80	216.00	259.20	302.40	345.60

Horse-Power of Shafting.

The Table 235 is calculated by means of the formula:—

$$HP = \frac{d^3 \times t}{125} \quad (4)$$

HP = horse-power

d = diameter of shaft in inches.

t = speed in turns per minute.

Toothed Wheels.

The Table 236 of the driving power of toothed wheels is based on the formula:—

$$HP = \frac{p \times f \times d \times t}{850} \quad (5)$$

HP = horse-power transmitted.

p = pitch in inches.

f = width of face of teeth, in inches.

d = diameter of wheel, in inches.

t = turns per minute

By this formula a pressure of about 150 pounds is exerted on the teeth of a wheel of 1 inch pitch and 1 inch face; with a proportionate stress on teeth of other pitches.

Weight of Cast-Iron Spur-Wheels of from 1 inch to 6 inches Pitch (Clark's Manual).

Applicable for diameters up to 20 feet.

$$W = (.05 + .08p) l \times (1 + 10d) \quad (6)$$

W = weight of wheel per inch of face, in cwts.

d = diameter in feet.

p = pitch in inches.

Weight of Cast-Iron Spur-Wheels of Pitches less than 1 inch.

Pitch.

$$\frac{7}{8} \quad W = .0935d + .0235d^2 \quad (7)$$

$$\frac{1}{2} \quad W = .069d + .0345d^2 \quad (8)$$

$$\frac{3}{8} \quad W = .080d + .0530d^2 \quad (9)$$

Mortise Wheels are of the same weight as spur-wheels of equal diameter.

Bevel Wheels and *Mitre Wheels* weigh from two-thirds to three-fourths of spur-wheels for the larger diameters, to seven-eighths for the smaller diameters.

TABLE 236.—HORSE-POWER OF TOOTHED WHEELS. (F. A. Halsey.)

Pitch of Teeth.	Diameter of Wheel in Inches.											
	6	9	12	15	18	21	24	30	36	42	48	54
Inches.	Horse-Power per Revolution per Minute and per Inch of Face											
	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP
1	.007	.011	.014	.018	.021	.025	.028	.035	.042	.049	.056	.064
1 1/2	.009	.013	.018	.022	.026	.031	.035	.044	.052	.062	.071	.088
1 3/4	.011	.015	.021	.026	.032	.037	.042	.053	.064	.074	.084	.106
2	.013	.019	.025	.031	.037	.043	.049	.062	.074	.084	.099	.123
2 1/2	.015	.021	.028	.035	.042	.049	.056	.071	.085	.097	.113	.138
3	.017	.024	.032	.040	.048	.056	.063	.080	.096	.111	.127	.156
3 1/2	.019	.026	.035	.044	.053	.062	.071	.088	.106	.123	.141	.176
4	.021	.029	.038	.048	.058	.068	.078	.100	.117	.136	.155	.194
4 1/2	.023	.031	.041	.051	.061	.071	.081	.105	.122	.143	.164	.206
5	.025	.034	.044	.055	.066	.077	.088	.114	.132	.154	.176	.222
6	.027	.037	.048	.059	.071	.083	.095	.123	.142	.166	.191	.240

TABLE 287.—TRANSMISSION OF POWER.
(Harpers.)

Toothed Wheels (Double Flanged Wheel one-third more powerful).				Steel Shafting		Single Belting.		One Rope	
Breadth of Teeth.	Pitch of Teeth	Power that can be transmitted per 100 Feet of Circum. Minute.		Diameter.	Power that can be transmitted per 10 Revolutions per Minute.	Breadth.	Power that can be transmitted for every 100 Feet of Velocity per Minute.	Diameter.	Power that can be transmitted for every 100 Feet of Velocity per Minute.
Inches	Inches.	Spur.	Bevel.	Inches.	H. P.	Inches.	H. P.	Inches.	H. P.
2	1	1	1	1 1/4	1	3	1	3/4	1
3	1 1/4	1 1/4	1 1/4	2	1 1/4	4	1 1/4	1 1/4	1 1/4
4	1 1/2	1 1/2	1 1/2	2 1/4	2 1/4	5	2 1/4	1 1/2	2 1/4
5	1 3/4	2	1 3/4	3	3 1/4	6	3 1/4	1 3/4	3 1/4
6	2	3 1/4	2 1/4	3 1/2	6	7	4 1/4	1 3/4	4 1/4
7	2 1/4	4 1/4	3 1/4	4	9	8	5 1/4	2	5 1/4
8	2 1/2	6 1/4	4 1/4	4 1/2	13	9	1	2 1/4	1
9	2 3/4	8 1/4	5 1/4	5	18	10	1 1/4	2 1/2	1 1/4
10	3	11 1/4	6 1/4	5 1/2	24	12	1 1/2	2 3/4	1 1/2
11	3 1/4	14 1/4	8 1/4	6	31	15	1 3/4	3	1 3/4
12	3 1/2	17 1/4	11	...	...	18	2 1/4	...	...
		19	14						

Friction-Wheel Gearing.

The grooves of friction-wheels are of V shape, forming the angle 50 degrees, usually at 4 inch pitch. Compared with leather belts, frictional gearing, worked under a pressure equal to the tension of the belts, has been proved to have greater adhesive force 30 per cent. more, in one case.

Transmission of Power (J. Bagshaw & Sons)

BELTING.—*To find the horse-power which can be transmitted by single leather belts.* Multiply the breadth of belt in inches by 70, and by the speed of belt in feet per minute, and divide by 33,000. The quotient is the horse-power.

Double belts transmit $1\frac{1}{2}$ times as much power as single belts.

To find the width of single belt for transmitting a given horse-power. Multiply the horse power by 33,000, and divide by 70 times the speed of the belt in feet per minute. The quotient is the width of belt in inches.

These rules are sufficiently approximate where there is no great degree of inequality in the diameters of the pulleys.

SHAFTING.—*To find the horse-power which can be transmitted by a wrought iron shaft.* Multiply the cube of the diameter of the shaft in inches by the number of revolutions per minute, and divide by 80. The quotient is the horse-power.

To find the diameter of a wrought iron shaft required to transmit a given horse-power. Multiply the horse-power by 80, and divide by the number of revolutions per minute. The cube root of the quotient is the diameter in inches.

ROPES. *To find the horse-power that can be transmitted by ropes.* Multiply the sectional area of one rope in square inches by 100 times the speed of the rope in feet per minute, and divide by 33,000. The quotient is the horse-power for one rope.

Or, multiply the sectional area of one rope by the speed and divide by 330.

TOOTHED WHEELS.—*To find the horse-power that can be transmitted by toothed wheels.* Multiply the velocity of the pitch-line in feet per second by the breadth of the teeth in inches, and by the square of the pitch in inches, and divide by 15. The quotient is the horse-power.

For bevel wheels, the mean diameter and mean pitch are to be taken.

TRANSMISSION OF MOTIVE POWER TO GREAT DISTANCES.

Transmission by Hemp Ropes.

For the driving gear of large steam engines, hemp ropes are much employed to take off the power from the circumference of the fly-wheel, which is grooved. The tension on the ropes is usually about 100lb. per square inch of section. The usual speed is from 4,500 to 5,500 feet per minute.

TABLE 238.—HORSE-POWER BY MANILLA ROPES.
(Leavitt.)

Speed of Rope, in Feet per Minute	1000	1500	2000	2500	3000	3500	4000	4500	5000
Diameter of Rope	Horse-Power								
Inches.									
$\frac{1}{4}$	14	21	28	35	42	51	61	7	9
1	3½	4½	6½	8	10	11	13	15	16
1½	5½	7½	10½	13	15	18	20	23	26
1½	7½	11	15	18	22	26	30	34	37
1½	10	15	20	25	30	35	40	45	50
2	13	19½	26	33	39	46	52	59	65

Transmission of Motive Power by Wire-Rope.

In one case, power was transmitted from a water-wheel through a horizontal distance of 400 feet by means of an iron wire-rope 433 inch in diameter, which passed over two grooved cast-iron pulleys 656 feet in diameter, lined in the groove with compressed and tarred leather. The rope was formed of a central ply of Bologna hemp, tarred, around which were twisted six strands, each of eight iron wires, $\frac{1}{16}$ inch thick, on a core of tarred hemp. The speed was brought up by toothed gearing in two stages, so that the motor pulley made 1904 turns for one of the water-wheel. For a speed of 20 turns per minute of the first intermediate shaft, the motor pulley makes 14585 turns, and the speed of its periphery is 50 feet per second, or 3000 feet per minute. At this speed, the loss by frictional resistance of the gearing and rope was 6.82 per cent.

Transmission of Motive Power by Compressed Air

The Paris Compressed Air Company supply air compressed by steam power, of 5 atmospheres pressure, to second engines of two types:—rotary engines for powers up to 2000

1 horse-power, and larger sized motors, up to double-cylinder engines having 12-inch cylinders with 14-inch stroke,—ordinary steam-engines employed for air. The secondary motor, when indicating 9.9 horse-power, and making 125 revolutions, according to Professor Kennedy, uses 890 cubic feet of air per indicator horse-power per hour. A small motor four miles distant from the central station, can indicate, in round numbers, 10 horse-power for 20 horse-power at the station, allowing for the value of the coke used in heating the air, or for 25 horse-power, if the air be not heated at all, making in the second instance an efficiency of 40 per cent.

Transmission of Domestic Motive Power by Atmospheric Exhaustion.

The distribution of power in dwelling-houses in Paris is effected by means of the exhaustion of air from a system of pipes, laid in the sewers for the most part, from which the power is supplied in small quantities to work the tools or machines employed in small industries. A vacuum, averaging 67 per cent or 20 inches of mercury,—occasionally reaching to 75 per cent or 22½ inches—is maintained in a reservoir 49 inches in diameter, 11½ feet in length, serving to regulate the pressure in the service pipes. These are 10 inches and 8 inches in diameter, from the pumping station to the sewer and 8 inches and 4 inches in the sewer or trench. The conduits do not exceed from 1 mile to 1½ miles in length. The secondary motors are of the trunk type, supplying powers of from $\frac{1}{25}$ th to 1 horse-power.

The air-cylinder utilises 93 per cent. of the engine-power transmitted. Of this the exhaust motors utilise a maximum of 60 per cent., the loss of head in the main is 5 per cent.; lastly, the air yields only 85 per cent. of its total capacity for work. The resulting coefficient is 43 per cent.; and the actual work of 1 cubic foot of air is 1246 foot pounds.

Transmission of Motive Power by Electricity.

This is easily effected, where the power does not exceed 3 horse-power, nor the distance 1½ miles. In experiments by M. Fontaine, the dynamos made 1,200 revolutions per minute. The power delivered at the periphery of the fly wheel of the steam engine was 95 horse-power, at the break, 50 horse-power, resistance of intermediate conductors (¼ inch copper wire, 77½ miles long) 100 ohms: 6,700 volts at origin of conducting line: intensity of current, 8 amperes: ultimate efficiency, 52.52 per cent.

In an experiment at the Manich Exhibition, in 1882, the generator was at Miesbach, and the electro-motor in Exhibition palace, 35½ miles apart. The conductor

double line of iron telegraph wire, $4\frac{1}{2}$ millimetres in diameter. The machines used were two similar Gramme dynamos, series wound. The resistance of each was 470 ohms, and that of the line 950 ohms, making the total resistance of circuit, $(950 + (470 \times 2)) = 1890$ ohms.

Generator, 1611 revolutions per minute; electromotive force = 1343 volts; current intensity .519 ampère.

Motor, 752 revolutions per minute; counter electromotive force = 850 volts.

Theoretical efficiency — $\frac{850}{1343} = .63$.

The power received at Munich was $\frac{1}{2}$ horse-power; and the economical efficiency was about 25 per cent.

TABLE 239.—RESULTS OF TRIALS.

	First Trial		Second Trial	
	Generator	Receiver	Generator	Receiver
Speed in revolutions per minute . . .	190	248	120	277
Electromotive force (direct or inverse) Volts	5469	4242	5717	4441
Current Ampères	7.21	7.21	7.20	7.20
Work in magnetic field H. P.	9.26	3.75	10.30	3.80
Electrical work in armature H. P.	53.59	41.44	55.00	43.10
Mechanical work measured in transmission dynamometer and at Prony brake. H. P.	62.10	35.80	61.00	40.00
Efficiency.				
	First Trial		Second Trial	
	Per Cent.		Per Cent.	
Electric	77.0		78.0	
Mechanical (commercial)	47.7		53.4	

See also *Hydraulic Transmission of Motor Power*, post.

HEAT.

The British unit of heat, or thermal unit, is that which can raise the temperature of one pound of water 1 degree Fahrenheit, at or near $39^{\circ}1$ F., the temperature of maximum density of water.

The French thermal unit, or *calorie*, is that which can raise the temperature of one kilogramme of water, 1 degree centigrade, at or about 4° C. ($39^{\circ}1$ F.).

1 calorie, or French unit of heat, is equal to 3.968 British heat-units.

1 British heat-unit is equal to .252 calorie.

The mechanical equivalent of one British heat-unit (Joule-equivalent) is 772 foot-pounds, or 10.67 kilogrammetres.

The mechanical equivalent of one French heat-unit is 423 kilogrammetres, or 3074 foot-pounds. If calculated in terms of Joule's equivalent, the value would be 423.53 kilogrammetres, or 3083.5 foot-pounds.

1 calorie per square metre is equal to .369 heat-unit per square foot.

1 heat-unit per square foot is equal to 2.713 calories per square metre.

1 calorie per kilogramme is equal to 1.800 heat-units per pound.

1 heat-unit per pound is equal to .556 calorie per kilogramme.

Thermometers.

	Freezing Point.	Boiling Point.
Fahrenheit thermometer	32°	212°
Centigrade ..	0°	100°
Reaumur ..	0°	80

1 degree Fahr. = $\frac{5}{9}$ Centigr. degree; or $\frac{4}{9}$ Reaumur degree.

1 degree Centigr. = $\frac{9}{5}$ Fahr. degree, or $\frac{9}{4}$ Reaumur degree.

1 degree Reaumur = $\frac{9}{4}$ Fahr. degree; or $\frac{5}{4}$ Centigr. degree.

Representing the thermometric scales by their initials.

Equivalent temperature by the Centigrade scale; $C. = \frac{5}{9}(F. - 32) = \frac{4}{9}R.$

do. by the Reaumur scale $R. = \frac{4}{9}(F. - 32) = \frac{4}{9}C.$

do. by the Fahrenheit scale $F. = \frac{9}{5}C. + 32 = \frac{9}{4}R. + 32.$

TABLE 240. — THERMOMETERS · FAHRENHEIT AND CENTI-
GRADE SCALES.

Fahr	Centigr.	Fahr	Centigr.	Fahr	Centigr.	Fahr	Centigr.
°	°	°	°	°	°	°	°
15	-9.45	69	20.56	110	43.34	151	66.11
20	-6.67	70	21.11	111	43.90	152	66.67
25	-3.90	71	21.67	112	44.45	153	67.23
30	-1.11	72	22.22	113	45.00	154	67.78
32	0.00	73	22.78	114	45.56	155	68.34
33	+0.56	74	23.33	115	46.11	156	68.90
34	1.11	75	23.90	116	46.67	157	69.45
35	1.67	76	24.45	117	47.23	158	70.00
36	2.22	77	25.00	118	47.78	159	70.56
37	2.78	78	25.56	119	48.34	160	71.11
38	3.33	79	26.12	120	48.90	161	71.67
39	3.90	80	26.67	121	49.45	162	72.23
40	4.45	81	27.23	122	50.00	163	72.78
41	5.00	82	27.78	123	50.56	164	73.34
42	5.56	83	28.33	124	51.11	165	73.90
43	6.11	84	28.89	125	51.67	166	74.45
44	6.67	85	29.45	126	52.23	167	75.00
45	7.23	86	30.00	127	52.78	168	75.56
46	7.78	87	30.55	128	53.34	169	76.11
47	8.34	88	31.11	129	53.90	170	76.67
48	8.89	89	31.67	130	54.45	171	77.23
49	9.45	90	32.22	131	55.00	172	77.78
50	10.00	91	32.78	132	55.56	173	78.34
51	10.56	92	33.33	133	56.11	174	78.90
52	11.11	93	33.89	134	56.67	175	79.45
53	11.67	94	34.45	135	57.23	176	80.00
54	12.23	95	35.00	136	57.78	177	80.56
55	12.78	96	35.56	137	58.34	178	81.11
56	13.34	97	36.11	138	58.90	179	81.67
57	13.90	98	36.67	139	59.45	180	82.23
58	14.45	99	37.23	140	60.00	181	82.78
59	15.00	100	37.78	141	60.56	182	83.34
60	15.56	101	38.34	142	61.11	183	83.90
61	16.11	102	38.90	143	61.67	184	84.45
62	16.67	103	39.45	144	62.23	185	85.00
63	17.23	104	40.00	145	62.78	186	85.56
64	17.78	105	40.56	146	63.34	187	86.11
65	18.34	106	41.11	147	63.90	188	86.67
66	18.89	107	41.67	148	64.45	189	87.23
	19.45	108	42.23	149	65.00	190	87.78
	20.00	109	42.78	150	65.56	191	88.34

TABLE 240.—THERMOMETERS (*continued*)

Fahr	Centigr.	Fahr	Centigr.	Fahr	Centigr.	Fahr	Centigr.
°	°	°	°	°	°	°	°
192	88.90	222	105.56	310	154.45	460	237.78
193	89.45	223	106.11	315	157.23	465	240.56
194	90.00	224	106.67	320	160.00	470	243.34
195	90.56	225	107.23	325	162.78	475	246.11
196	91.11	226	107.78	330	165.56	480	248.90
197	91.67	227	108.33	335	168.34	485	251.67
198	92.23	228	108.90	340	171.11	490	254.45
199	92.78	229	109.45	345	173.90	495	257.23
200	93.34	230	110.00	350	176.67	500	260.00
201	93.90	232	111.11	355	179.45	505	262.78
202	94.45	234	112.23	360	182.23	510	265.56
203	95.00	236	113.34	365	185.00	515	268.34
204	95.56	238	114.45	370	187.78	520	271.11
205	96.11	240	115.56	375	190.56	525	273.90
206	96.67	242	116.67	380	193.34	530	276.67
207	97.23	244	117.78	385	196.11	535	279.45
208	97.78	246	118.90	390	198.90	540	282.23
209	98.34	248	120.00	395	201.67	545	285.00
210	98.90	250	121.11	400	204.45	550	287.78
211	99.45	255	123.90	405	207.23	555	290.56
212	100.00	260	126.67	410	210.00	560	293.34
213	100.56	265	129.45	415	212.78	565	296.11
214	101.11	270	132.23	420	215.56	570	298.90
215	101.67	275	135.00	425	218.34	575	301.67
216	102.23	280	137.78	430	221.11	580	304.45
217	102.78	285	140.56	435	223.90	585	307.23
218	103.34	290	143.34	440	226.67	590	310.00
219	103.90	295	146.11	445	229.45	595	312.78
220	104.45	300	148.90	450	232.23	600	315.56
221	105.00	305	151.67	455	235.00		

TABLE 241. THERMOMETERS: CENTIGRADE AND FAHRENHEIT SCALES.

Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.
°	°	°	°	°	°	°	°
-10	14.0	3	37.4	8	46.4	13	55.4
-5	23.0	4	39.2	9	48.2	14	57.2
0	32.0	5	41.0	10	50.0	15	59.0
+1	33.8	6	42.8	11	51.8	16	60.8
2	35.6	7	44.6	12	53.6	17	62.6

TABLE 241.—THERMOMETERS (*continued*)

Centigr	Fahr.	Centigr	Fahr.	Centigr	Fahr.	Centigr	Fahr.
°	°	°	°	°	°	°	°
18	64.4	60	140.0	102	213.6	158	316.4
19	66.2	61	141.8	103	217.4	160	320.0
20	68.0	62	143.6	104	219.2	162	323.6
21	69.8	63	145.4	105	221.0	164	327.2
22	71.6	64	147.2	106	222.8	166	330.8
23	73.4	65	149.0	107	224.6	168	334.4
24	75.2	66	150.8	108	226.4	170	338.0
25	77.0	67	152.6	109	228.2	172	341.6
26	78.8	68	154.4	110	230.0	174	345.2
27	80.6	69	156.2	111	231.8	176	348.8
28	82.4	70	158.0	112	233.6	178	352.4
29	84.2	71	159.8	113	235.4	180	356.0
30	86.0	72	161.6	114	237.2	182	359.6
31	87.8	73	163.4	115	239.0	184	363.2
32	89.6	74	165.2	116	240.8	186	366.8
33	91.4	75	167.0	117	242.6	188	370.4
34	93.2	76	168.8	118	244.4	190	374.0
35	95.0	77	170.6	119	246.2	192	377.6
36	96.8	78	172.4	120	248.0	194	381.2
37	98.6	79	174.2	121	249.8	196	384.8
38	100.4	80	176.0	122	251.6	198	388.4
39	102.2	81	177.8	123	253.4	200	392.0
40	104.0	82	179.6	124	255.2	202	395.6
41	105.8	83	181.4	125	257.0	204	399.2
42	107.6	84	183.2	126	258.8	206	402.8
43	109.4	85	185.0	127	260.6	208	406.4
44	111.2	86	186.8	128	262.4	210	410.0
45	113.0	87	188.6	129	264.2	212	413.6
46	114.8	88	190.4	130	266.0	214	417.2
47	116.6	89	192.2	132	269.6	216	420.8
48	118.4	90	194.0	134	273.2	218	424.4
49	120.2	91	195.8	136	276.8	220	428.0
50	122.0	92	197.6	138	280.4	222	431.6
51	123.8	93	199.4	140	284.0	224	435.2
52	125.6	94	201.2	142	287.6	226	438.8
53	127.4	95	203.0	144	291.2	228	442.4
54	129.2	96	204.8	146	294.8	230	446.0
55	131.0	97	206.6	148	298.4	232	449.6
56	132.8	98	208.4	150	302.0	234	453.2
57	134.6	99	210.2	152	305.6	236	456.8
58	136.4	100	212.0	154	309.2	238	460.4
59	138.2	101	213.8	156	312.8	240	464.0

TABLE 241. THERMOMETERS (*continued*).

Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.
°	°	°	°	°	°	°	°
242	467.6	262	503.6	282	539.6	302	575.6
244	471.2	264	507.2	284	543.2	304	579.2
246	474.8	266	510.8	286	546.8	306	582.8
248	478.4	268	514.4	288	550.4	308	586.4
250	482.0	270	518.0	290	554.0	310	590.0
252	485.6	272	521.6	292	557.6	312	593.6
254	489.2	274	525.2	294	561.2	314	597.2
256	492.8	276	528.8	296	564.8	316	600.8
258	496.4	278	532.4	298	568.4	318	604.4
260	500.0	280	536.0	300	572.0	320	608.0

TABLE 242. HIGH TEMPERATURES AND CORRESPONDING LUMINOSITY. (Pouillet.)

I. TEMPERATURE OF A FIRE.

	Centigrade	Fahrenheit.
	°	°
Nascent red	525	977
Dark red	700	1292
Nascent cherry red	800	1472
Cherry red	900	1652
Bright cherry red	1000	1832
Very deep orange	1100	2012
Bright orange	1200	2192
White	1300	2372
Dazzling white	1500	2732

II. TEMPERATURE BY FUSION OF METALS &c

Substance.	Temperature.	Metal	Temperature.	Metal.	Temperature.
	Fahr.		Fahr.		Fahr.
Tallow	92	Bismuth	518	Silver, pure	1830
Spermaceti	120	Lead	630	Gold coin	2156
Wax, white	154	Zinc	793	Iron, cast,	2010
Sulphur	230	Antimony	820	med.	
Tin	475	Brass	1650	Steel	2550
				Wrought	2910
				iron	

Radiation of Heat.

The heat radiated from incandescent coal or coke is expressed by the formula,—

$$R = 144 a^{\theta} (a^t - 1) \quad (1)$$

R —quantity of heat radiated per square foot of surface per hour, in British units.

θ —temperature of the enclosure, in Fahrenheit degrees.

t —excess temperature of surface of hot body above the temperature of the enclosure, θ , in Fahrenheit degrees.

a —constant, 1.00425.

According to the formula, the rate of radiation increases in much more rapid ratio than the excess temperature, when the temperature of the enclosure is constant.

The heat radiated from a coal or a coke fire, is estimated to be about one half of the whole heat generated. It increases almost as fast as the rate of combustion of the fuel per hour per square foot.

Convection of Heat, from an External Surface (Hopkins).

Surrounding Medium.

Air $C = 2849t + 238$ (2)

Hydrogen $C = 9827t + 233$ (3)

Carbonic acid $C = 2759t + 233$ (4)

Olefiant gas $C = 3817t + 233$ (5)

C —quantity of heat, in English units, conveyed away from a solid body by a gas external to it, per square foot of surface per hour, under one atmosphere of pressure.

t —excess temperature of surface in Fahrenheit degrees.

TABLE 243. COMPARATIVE CONDUCTING POWER OF SOLIDS.

Substance.	Comparative Power	Substance.	Comparative Power.
	Gold=1000.		Gold=1000.
Brass .	749	Platinum .	981
Copper .	892	Porcelain .	12
Gold .	1000	Silver .	973
Iron, cast .	562	Terra Cotta .	11
“ wrought .	474	Tin .	304
Lead .	180	Zinc .	363
Marble .	24		

TABLE 244.—COMPARATIVE ABSORBING OR RADIATING AND REFLECTING PROPERTIES OF SOLIDS.

Substance.	Absorbing or Radiating Power.	Reflecting Power
	Proportion per Cent.	Proportion per Cent.
Brass, bright polished . . .	7	93
„ dead polished . . .	11	89
Copper	7	93
Glass	90	10
Gold	5	95
Ice	85	15
Iron, cast, polished . . .	25	75
„ wrought, polished . . .	23	77
Marble	98 to 98	7 to 2
Mercury	23	77
Platinum, polished . . .	24	76
„ sheet	17	83
Silverleaf on glass . . .	27	73
Silver, polished	3	97
Steel, polished	17	83
Tin	15	85
Water	100	0
Writing paper	98	2
Zinc, polished	19	81

Condensation of Steam in bare Pipes exposed to Air.

Tredgold found that steam of 17½ lbs. absolute pressure per square was condensed in cast-iron pipes in a room at 60° F., at the rate of .352 pound per square foot of exposed surface per hour; or .0022 pound per degree of difference of temperature.

The following results were found by M. Clément. It is here assumed that the steam was of 20 lbs. absolute pressure per square inch. The pipes were exposed in a room at 77° F.

Bare Surface.	Steam Condensed per Square Foot per Hour.
Cast-iron pipe, horizontal . . .	.328 lb.
Blackened „ „ . . .	.308 „
Copper „ „ . . .	.267 „
Blackened „ „ . . .	.308 „
„ „ upright . . .	.359 „

M. Buriat found that for steam of 22 lbs. absolute pressure, with 196°·6 F. difference of temperature, 581 lb. was condensed per square foot of a cast-iron pipe, nearly horizontal, per hour.

Dr. William Anderson experimented with a tubular steam-heater, of 2 inch wrought-iron tubes, in a temperature of 59° F., with steam of 51 lbs. total pressure per square inch; 785 lb. was condensed per square foot per hour.

The foregoing results are collected in the following table

Observer.	Temperature of surrounding Air	Difference of Temperature.	Steam consumed per Square Foot per Hour		Heat emitted per 1° F. difference of Temperature.
			Total.	Per 1° F.	
	" Fahr.	" Fahr.	Pounds	Pounds	Units.
Clement	17	171	328	·00211	2·07
Tredgold.	60	161	852	·0022	2·10
Buriat	36·3	196·6	581	·0030	2·81
Anderson	59	223	785	·0035	3·22

From these data, the following approximate formulæ are deduced:—

Condensation of steam in cast-iron pipes, in air, per square foot of surface per hour at ordinary temperatures:—

$$s = \frac{t^2}{55(\text{K})} \cdot 12 \quad (6)$$

Heat emitted from cast-iron pipes, in air, per square foot of surface per hour, at ordinary temperatures:—

$$h = \frac{t^2}{58} \cdot 114 \quad (7)$$

Heat emitted from cast-iron pipes, in air, per square foot of surface per degree of difference of temperature of steam and air, per hour, at ordinary temperatures,

$$h' = \frac{t}{58} \cdot 114 \quad (8)$$

s —quantity of steam condensed in pounds.

h —quantity of heat emitted in units

h' —quantity of heat emitted, per degree of difference of temperature.

t —difference of temperature, in Fahrenheit degrees.

The latent heat of steam, of 22 lbs. total pressure per square inch, 950 units per pound, is employed as the heat-factor, an average value.

The Table 245 has been calculated by means of the formulas.

TABLE 245.—STEAM CONDENSED IN BARE CAST-IRON PIPES IN AIR, AND HEAT EMITTED, AT ORDINARY TEMPERATURES.

STEAM		Difference or Excess of Temperature of Steam above 62° Fahr	STEAM CONDENSED per Square Foot per Hour		HEAT EMITTED per Square Foot per Hour.	
Total Pressure per Square Inch	Temperature.		Total	Per 1° F. of Difference	Total.	Per 1° F. of Difference
Pounds.	Fahr.	Fahr.	Lbs.	Pounds.	Units.	Units.
14.7	212	150	29	0.0193	276	1.84
18	220	160	346	0.0316	329	2.05
21.5	232	170	405	0.0238	384	2.26
26	242	180	47	0.0261	446	2.48
31	252	190	54	0.0284	513	2.70
36.5	262	200	607	0.0303	577	2.89
43	272	210	682	0.0325	648	3.08
51	282	220	76	0.0345	722	3.28

For the increased rate of condensation induced by a draught of air, compared with that caused in the still air of a room, bare steam boiler, in open air, was tested. Steam of 50 lb. absolute pressure per square inch was condensed at the rate of 1.25 pounds per square foot of external surface per hour, or, for a difference of 256° of temperature, .0053 pound per degree of difference; showing that 4.79 units of heat per degree was emitted, or a half more than from a pipe in still air.

Non-Conducting Coating for Steam Pipes.

M. Burnat's experiments were made with cast iron steam pipes, 4.72 inches in diameter externally, $\frac{1}{4}$ inch thick, in a large unheated hall free from draughts. They were in five groups differently coated:—

1st group, coated with straw laid lengthwise, .60 inch thick wrapped with straw rope.

2nd group, bare.

3rd group. Each pipe laid in a pottery pipe, enclosing an air-space, coated with a mixture of foamy earth and chopped straw, covered with tresses of straw.

4th group, coated with cotton-waste, 1 inch thick, wrapped in cloth bound with cord.

5th group, coated with a plaster of clay and cow's hair, 2-36 inches thick.

The results are given in Table 246

TABLE 246. CONDENSATION OF STEAM IN COATED PIPES.
(BURNAL.)

Absolute Pressure of Steam per Square Inch	Temperatures.			Steam condensed per Square Foot of External Surface of Pipes per Hour.				
	Steam	Air	Difference.	Straw coat, 1st.	Bare, 2nd.	Pottery coat, 3rd.	Waste coat, 4th.	Plaster coat, 5th.
Lbs.	Fahr	Fahr	Fahr	Lb.	Lb.	Lb.	Lb.	Lb.
16.5	218.0	46.4	171.6	139	493	170	217	254
16.5	218.0	33.8	184.2	152	485	163	205	262
18.4	223.4	33.7	189.7	161	555	186	229	287
18.4	223.4	27.1	196.4	182	571	264	287	344
22.0	233.2	41.5	191.7	216	570	258	244	320
22.0	233.2	36.5	196.7	164	...	158	250	...
22.0	233.2	36.1	197.1	162	557	178	260	...
22.0	233.2	28.3	204.9	201	586	264	328	346
25.7	241.6	43.3	198.4	214	645	301	375	389
25.7	241.6	36.5	205.1	274	...	285	369	...
29.4	249.1	43.3	205.8	252	721	270	342	379
29.4	249.1	30.6	218.4	225	621	250	328	336
Averages, 22.0	233.1	36.5	196.6	200	581	229	286	324

The plaster coat, fifth group, was afterwards painted white, when an average of 307 pound of steam was condensed per square foot per hour, against 324 pound previously.

The bare pipe was afterwards coated with old felt, which had been treated with caoutchouc, and it condensed an average of 313 pound of steam per square foot per hour.

The rates of condensation and of emission of heat are summarised as follows:—

TABLE 247.—SUMMARY RESULTS.

Coating of Pipe.	Steam Condensed per Square Foot per Hour.		Heat Emitted per Square Foot per Hour.	
	Total.	Per 1° F. Difference.	Total.	Per 1° F. Difference.
	Pound.	Pound.	Units.	Units.
Bare pipe	·581	·00300	552·8	2·812
Straw	·200	·00102	190·3	0·968
Pottery pipes with air-space	·229	·00115	224·8	1·108
Cotton waste	·286	·00146	272·1	1·384
Felt	·313	·00159	297·8	1·515
Plaster	·324	·00165	308·3	1·568
The same, painted white	·307	·00156	292·1	1·486

Cooling of Water in Pipes exposed to Air.

Mr. Wm. Anderson experimented with 2-inch wrought-iron pipes, $\frac{3}{16}$ inch thick, galvanised, and 4-inch cast-iron pipes, $\frac{7}{16}$ inch thick, through which hot water was passed. Results are given in Table 248. The ultimate results harmonise with those for the use of steam in pipes.

TABLE 248.—COOLING OF WATER IN PIPES EXPOSED TO AIR.

	Two-Inch Wrought-iron Pipes.				Four-Inch Cast-iron Pipes.			
	1	2	3	4	1	2	3	4
Number of experi- ment	1	2	3	4	1	2	3	4
Temperature of the atmosphere Fahr.	53°	53°	52°·5	52°	60°	60°	60°	59°
Average difference of temperatures of the water and the air . Fahr.	103·7	49·4	25·4	14·3	62·3	45·8	33·9	27·3
Total heat emitted per square foot per hour. Units	233·7	104·4	46·45	19·7	99·5	69·9	49·5	88·2
Heat emitted per 1° F. difference of temperature Units.	2·25	2·11	1·83	1·39	1·59	1·53	1·46	1·40

Tredgold experimented with small vessels of different materials, in which water was cooled from a temperature of 180° to one of 159° , in a room at 55° . The heat emitted per square foot per hour per degree of mean difference of temperature was as follows:—

Tin-plate	1.37 units.
Sheet-iron	2.24 „
Glass	2.18 „

Also, in a $2\frac{1}{2}$ inch cast-iron pipe, $\frac{1}{4}$ inch thick, water was cooled from 152° to 140° F., in a room at 67° . The heat emitted per square foot per hour per degree of difference of temperature was as follows:—

Ordinary rusty surface	1.823 units.
Black, varnished	1.900 „
White (two coats of lead paint)	1.778 „

Transmission of Heat through Metal Plates from Water to Water.

In a metal tubular refrigerator, hot wort was cooled by water at such a rate that, taking averages, 80 units of heat passed from the wort, and was absorbed by the water per square foot of cooling surface per 1° F. per difference of temperature. The water and the wort were moved in opposite directions.

M. Péciot proved experimentally that the rate of transmission of heat was directly as the difference of temperature at the two faces of metal plates.

Transmission of Heat through Metal Plates from Steam to Water.

The rate of transmission of heat from steam through a metal plate to water at the other side is practically uniform per degree of difference of temperature. The following Table gives average results of performance, from which it appears that the transmission is much more effective for evaporating than for heating water, twice as much for flat copper plate, three times as much for copper pipe, one-fourth more for cast-iron plate. Also that pipe surface is one-fifth more effective than flat plate surface for heating, and more than twice as much for evaporation—the result of better circulation, no doubt.

TABLE 250.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (Board of Trade).

	For 1° Fahr.	For 1° Cent.	Expansion between Freezing and Boiling Points		Coefficient in length of Ten Feet	Coefficient in Fraction
			Coefficient.	In length of Ten Feet		
Aluminium (cast)	.00001284	.0000221	.002221	.02221	.2664	$\frac{1}{370}$
Antimony (cryst.)	.00000627	.00001129	.01129	.01129	.1336	$\frac{1}{752}$
Brass cast	.00000937	.00001722	.01722	.01722	.2066	$\frac{1}{485}$
English plate	.00001072	.00001894	.001894	.01894	.2278	$\frac{1}{439}$
" sheet	.00001040	.00001872	.001872	.01872	.2246	$\frac{1}{445}$
Brick, best stock	.00000306	.00000550	.000550	.00550	.0660	$\frac{1}{1515}$
Bronze (Rail's)						
Copper, 17	.00000986	.00001774	.001774	.01774	.2129	$\frac{1}{469}$
Tin, 24						
Zinc, 1						
"						
Cement, Roman, dry	.00000975	.00001755	.001755	.01755	.2106	$\frac{1}{468}$
" Portland (mixed), pure	.00000797	.00001435	.001435	.01435	.1722	$\frac{1}{580}$
" " mortar, with sand	.00000594	.00001070	.001070	.01070	.1284	$\frac{1}{780}$
Concrete cement mortar and pebbles	.00000556	.00001180	.001180	.01180	.1416	$\frac{1}{706}$
Copper	.00000795	.00001430	.001430	.01430	.1716	$\frac{1}{582}$
Granite	.00000887	.00001596	.001596	.01596	.1918	$\frac{1}{521}$
	.00000920	.00001676	.001676	.01676	.2012	$\frac{1}{497}$

condenser brass tube, $\frac{3}{4}$ inch in diameter outside, No. 18 wire-gauge in thickness : encased in a $3\frac{1}{4}$ inch iron pipe. Steam of $32\frac{1}{2}$ lbs total pressure per square inch occupied the interspace, whilst cold water at 58° F initial temperature was run through the brass tube. Three experiments were made with the tubes in a vertical position, and three in a horizontal position.

Vertical Position.			Horizontal Position.		
1,	2,	3,	4,	5,	6,
Velocity of water through tube, in feet per minute,—					
81,	278,	390,	78,	307,	415 feet.

Steam condensed per square foot of surface per hour, for 1° F. difference of temperature,—

335,	436,	457,	480,	603,	699 lb.
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Heat absorbed by the water, per square foot per hour, per 1° F. difference of temperature,—

346,	449,	466,	479,	621,	696 units.
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The rate of condensation was greater in the horizontal position than in the vertical position. Also, the efficiency of the condensing surface was increased by an increase of velocity of the water through the tube, nearly in the ratio of the fourth root of the velocity for vertical tubes, and nearly as the $4\frac{1}{2}$ root for horizontal tubes.

Transmission of Heat through Metal Plates or Tubes, from Air or other Dry Gas to Water.

The rate of transmission of convected heat is probably from 2 to 5 units of heat per hour per square foot of surface per 1° F. of difference of temperature.

In a locomotive fire-box, where radiant heat co-operated with convected heat, the following results have been obtained in generating steam of 80 lbs. pressure per square inch. The temperature of the fire is taken at 2000° F.

	Water Evaporated per Square Foot per Hour.	Heat Transmitted per Square Foot per Hour per 1° F. diffe- rence of Temperature
Burning coke, 75 lbs. per square foot of grate	25 $\frac{1}{2}$ lbs.	14 $\frac{1}{2}$ units.
Burning briquettes, 74 $\frac{1}{2}$ lbs. per square foot of grate	35 "	20 "

There are in practice little or no differences between iron, copper, and lead in evaporative activity, when the surfaces are *dimmed* or coated, as under ordinary conditions.

TABLE 250.- LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (continued)

	For 1° Fahr.		For 1° Cent.		Expansion between Freezing and Boiling Points.		Common Fraction
	Length 1.		Length = 1.		Coefficient	In length of Ten Feet	
Marble black Galway.	0.0000308		0.0000354		0.00554	Foot 0.0554	$\frac{1}{1800}$
" Carrara	0.0000471		0.0000848		0.00848	1018	$\frac{1}{1179}$
Masonry of brick in cement-mortar leaders	0.00003494		0.0000890		0.00890	1068	$\frac{1}{1148}$
Do. do. stretchers	0.0000256		0.0000460		0.00460	0.552	$\frac{1}{1775}$
Mercury (cubic expansion).	0.0000984		0.0017971		0.17971	21567	$\frac{1}{45}$
Ni. ke.	0.0000695		0.0001251		0.01251	1501	$\frac{1}{66}$
Osmium	0.0000317		0.0000576		0.00576	684	$\frac{1}{144}$
Paladium, pure	0.0000751		0.0001400		0.01400	1200	$\frac{1}{83}$
powder.	0.0001120		0.0002083		0.02083	2440	$\frac{1}{41}$
plaster white	0.0000922		0.0001660		0.01660	1992	$\frac{1}{50}$
platinum	0.0000479		0.0000863		0.00863	1036	$\frac{1}{116}$
platinum, 90 per cent.	0.0000476		0.0000857		0.00857	1028	$\frac{1}{117}$
Iridium, 10 per cent. hammered and annealed	0.0000453		0.0000815		0.00815	978	$\frac{1}{102}$
plat num, 85 per cent	0.0000390		0.0000720		0.00720	864	$\frac{1}{115}$
Iridium, 15 per cent. porcelain	0.0000390		0.0000720		0.00720	864	$\frac{1}{115}$

TABLE 250.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (continued).

	For 1° Fahr.	For 1° Cent.	Expansion between Freezing and Boiling Points.		Common Fraction.
			Coefficient	In length of Ten Feet.	
	Length = 1	Length = 1		Foot.	Inch
Glass, English flint	.00000451	.00000812	.000812	.00812	$\frac{1}{124}$
" French flint	.00000484	.00000872	.000892	.00892	$\frac{1}{121}$
" white, free from lead	.00000492	.00000886	.000886	.00886	$\frac{1}{120}$
" blown	.00000498	.00000896	.000896	.00896	$\frac{1}{119}$
" thermometer	.00000499	.00000897	.000897	.00897	$\frac{1}{119}$
" hard	.00000497	.00000897	.000714	.00714	$\frac{1}{140}$
Granite, grey, dry	.00000438	.00000789	.000789	.00789	$\frac{1}{126}$
" red	.00000498	.00000897	.000897	.00897	$\frac{1}{117}$
Gold, pure	.00000788	.00001415	.001415	.01415	$\frac{1}{70}$
Iridium, pure	.00000556	.00000641	.000641	.00641	$\frac{1}{156}$
Iron, wrought	.00000648	.00001166	.001166	.01166	$\frac{1}{86}$
" Swedish	.00000686	.00001145	.001145	.01145	$\frac{1}{87}$
" cast	.00000556	.00001001	.001001	.01001	$\frac{1}{100}$
" soft	.00000626	.00001126	.001126	.01126	$\frac{1}{87}$
Lead	.00001571	.00002828	.002828	.02828	$\frac{1}{35}$
Matte, moist	.00000663	.00001193	.001193	.01193	$\frac{1}{83}$
" dry	.00000568	.00000654	.000654	.00654	$\frac{1}{153}$
" white Sicilian, dry	.00000789	.00001415	.001415	.01415	$\frac{1}{70}$

Comparative Rate of Emission of Heat from Steam Pipes in Air and in Water.

It appears that for equal total difference of temperature, the rate of emission of heat from steam pipes in water amounts, in round numbers, to from 150 to 250 times the rate in air, according as the pipes are vertical or horizontal.

Comparative Rate of Emission of Heat from Water-Tubes in Air and in Water at Rest and in Motion.

It appears that the rate of emission from water-tubes in water was about twenty times the rate in air. Mr. Craddock proved it experimentally to be twenty-five times. When the water tube was moved through the air at a speed of 59 feet per second, it was cooled in one-twelfth of the time occupied in still air. In water, moved at a speed of 3 feet per second, the water in the tube was cooled in half the time.

Expansion of Liquids.

The cubical expansion, or expansion of volume, of water, from 32° F. to 212° F. and upwards, is given in Table 251. The rate of expansion increases with the temperature. The expansion for the range of temperature from 32° to 212° is .0466, or fully $4\frac{1}{2}$ per cent. of the volume at 32°; or an average of .000259 per degree, or $\frac{1}{3885}$ part of the volume at 32° F.

TABLE 251. — EXPANSION OF LIQUIDS, FROM 32° TO 212° F.
Volume at 32° = 1.

Liquid	Volume at 212°	Expansion	Liquid	Volume at 212°	Expansion
Alcohol	1.1100	$\frac{1}{9}$	Sea water	1.0500	$\frac{1}{20}$
Nitric acid	1.1100	$\frac{1}{9}$	Water	1.0466	$\frac{1}{21}$
Olive oil	1.0800	$\frac{1}{12}$	Mercury	1.018	$\frac{1}{50}$
Turpentine	1.0700	$\frac{1}{14}$			

TABLE 252.—EXPANSION AND WEIGHT OF WATER AT VARIOUS TEMPERATURES.

Temperature.	Relative Volume by Expansion.	Weight of One Cubic Foot.	Weight of One Gallon.	Temperature.	Relative Volume by Expansion.	Weight of One Cubic Foot.	Weight of One Gallon.
Fahr.		Pounds.	Pounds.	Fahr.		Pounds.	Pounds.
32	1.00000	62.418	10.0101	100	1.00639	62.022	9.947
35	99993	62.422	10.0103	105	1.00735	61.960	9.937
		62.425		110	1.00839	61.898	9.922
39.1	99989	max- imum density	10.0112	115	1.00939	61.807	9.913
40	99989	62.425	10.0112	120	1.01139	61.715	9.897
45	99993	62.422	10.0103	125	1.01239	61.654	9.887
46	1.00000	62.418	10.0101	130	1.01339	61.565	9.873
50	1.00015	62.409	10.0087	135	1.01539	61.472	9.859
		62.400		140	1.01839	61.381	9.844
		ordinary calcula- tions.		145	1.01989	61.291	9.829
52.3	1.00029		10.0072	150	1.02164	61.201	9.815
55	1.00038	62.394	10.0063	155	1.02340	61.101	9.781
60	1.00074	62.372	10.0053	160	1.02589	60.943	9.767
62				170	1.02690	60.783	9.748
mean tem- pera- ture	1.00101	62.355	10.0000	175	1.02906	60.665	9.728
65	1.00119	62.344	9.9982	180	1.03100	60.548	9.711
70	1.00160	62.313	9.9933	185	1.03300	60.430	9.691
75	1.00239	62.275	9.9871	190	1.03500	60.314	9.672
80	1.00290	62.232	9.980	195	1.03700	60.198	9.651
85	1.00379	62.182	9.972	200	1.03889	60.081	9.635
90	1.00479	62.133	9.964	205	1.0414	59.93	9.611
95	1.00554	62.074	9.955	210	1.0434	59.82	9.594
				212	1.0466	59.64	9.565
				250	1.06243	58.75	9.422
				300	1.09563	56.97	9.136
				400	1.17056	54.27	8.700
				500	1.22065	51.16	8.204

Expansion of Gases.

The volume of atmospheric air is increased in the ratio of 1 to 1.365, in raising a temperature from 32° to 212° F., under constant pressure, and when the volume is constant, the pressure is increased in the ratio of 1 to 1.365.

The expansion under constant pressure is uniform, and is at the rate of $\frac{1}{273}$ part of the volume at 32° F., for each degree of rise of temperature—say the fraction $\frac{1}{273}$. At this rate of

contraction the absolute zero of the Fahrenheit scale, or point of no heat, is $(493 - 82 =) -461^{\circ} \text{F.}$, or 461° below 0° on the scale. On the Centigrade scale, the absolute zero is -273° . The absolute temperature by the Fahrenheit scale is found by adding 461 to the temperature indicated on the thermometrical scale. For a given volume of air or other gases at a given temperature, the volume for any other temperature under a constant pressure is,—

$$V' = V \frac{t' + 461}{t + 461} \quad (9)$$

When the initial temperature is 62°F. , the formula becomes

$$V' = V \frac{t' + 461}{523} \quad (10)$$

When the temperature is constant, the volume varies as the pressure, or

$$V' = V \frac{p}{p'} \quad (11)$$

When the temperature and pressure change,—

$$V' = V \frac{p(t' + 461)}{p'(t + 461)} \quad (12)$$

When the initial temperature is 62°F. , and the initial pressure is 14.7 lbs. per square inch, the formula becomes

$$p' = \frac{V(t' + 461)}{35.58 V'} \quad (13)$$

When in addition the volume is constant, this formula becomes

$$p' = \frac{t' + 461}{35.58} \quad (14)$$

The product of the volume and pressure of a constant weight of a gas varies as the absolute temperature.

$$(1 \text{ pound of air}) Vp = \frac{(t + 461)}{2.7074} \quad (15)$$

And the volume of one pound of air at any pressure and any temperature, is

$$V = \frac{(t + 461)}{2.7074 p} \quad (16)$$

V = initial volume of gas.

V' = final volume of gas.

t = initial temperature.

t' = final temperature.

p = initial pressure.

p' = final pressure.

Specific Heat.

The specific heat of a body is its capacity for heat relative to that of water as a standard, of which the specific heat is that required to raise the temperature of 1 pound of water at 32° F., one degree Fahrenheit; in short, the British unit of heat. The specific heat of water is not constant, but increases slightly with the temperature, in so much that the heat required to raise the temperature from 32° to 212° F., through 180 degrees, is 180.9 units; and the average specific heat is 1.005, or one-half per cent. more than that at 32° F.

The specific heat of all solids and liquids is variable, gradually augmenting with the temperature. For temperatures under 212°, they are nearly constant.

The specific heat of perfect gases is constant.

TABLE 253.—SPECIFIC HEAT OF METALS.

Antimony	0507	Manganese	1441
Bismuth	0308	Mercury, solid	0319
Brass	0939	.. liquid	0333
Copper	0951	Nickel	1086
Cymbal metal	086	Platinum, sheet	0324
Gold	0324	.. spongy	0329
Iridium	1887	Silver	0570
Iron, cast	1298	Steel	1165
.. wrought	1138	Tin	0669
Lead	0314	Zinc	0955

TABLE 254.—SPECIFIC HEAT OF OTHER MINERAL SUBSTANCES.

STONES.		CARBONACEOUS.	
Brickwork and masonry	20	Graphite, natural	2019
Marble	2129	.. of blast furnaces	497
Chalk	2148		
Quicklime	2169	SUNDRY.	
Magnesian limestone	2174	Glass	1977
		Ice	504
CARBONACEOUS.		Phosphorus	2503
Coal	3411	Soda	2311
Charcoal	2415	Sulphate of lead	0872
Cannel coke	2031	.. lime	1935
Coke of pit coal	2008	Sulphur	200
Anthracite	2017		

TABLE 255 SPECIFIC HEAT OF LIQUIDS.

Alcohol	6588	Tarrentine	416
Benzine	3932	Vinegar	920
Mercury	0334	Water, at 32° F.	1.000
Olive oil	3096	" 212° F.	1.015
Sulphuric acid		" 32° to 212° F.	1.005
Density, 1.87	3345	Wood spirit	500
" 1.30	6514		

TABLE 256 -SPECIFIC HEAT OF GASES.

For Equal Weights.	At Constant Pressure.	At Constant Volume.
Air . . . . .	.2377	.1688
Carbonic acid (CO_2) . . . . .	.2164	.1714
" oxide (CO}) . . . . .	.2479	.1768
Hydrogen	3.4046	2.4096
Light carburetted hydrogen . . . . .	.5929	.4683
Nitrogen . . . . .	.2440	.1740
Oxygen . . . . .	.2182	.1559
Steam, saturated . . . . .	...	.3050
Steam gas . . . . .	.4750	.3700
Sulphurous acid . . . . .	.1553	.1246

TABLE 257 -SPECIFIC HEAT OF WATER AT VARIOUS TEMPERATURES.

Tempe- rature.	Specific Heat.	Heat to raise 1 lb. of Water from 32° F. to given Temperature.	Tempe- rature	Specific Heat.	Heat to raise 1 lb. of Water from 32° F. to given Temperature.
Fahr		Units.	Fahr		Units.
32	1.0000	0.000	248	1.0177	217.449
50	1.0005	18.004	266	1.0204	235.791
68	1.0012	36.018	284	1.0232	254.187
86	1.0020	54.047	302	1.0262	272.628
104	1.0030	72.090	320	1.0294	291.132
122	1.0042	90.157	338	1.0328	309.690
140	1.0056	108.247	356	1.0364	328.320
158	1.0072	126.378	374	1.0401	347.004
176	1.0089	144.508	392	1.0440	365.760
194	1.0109	162.686	410	1.0481	384.588
212	1.0130	180.900	428	1.0524	403.488
230	1.0153	199.152	446	1.0568	422.475

TABLE 258.—SPECIFIC HEAT OF WOODS.

Turpentine	467	Oak	570
Pear tree	500	Fir	550

TABLE 259.—VOLUME OF 1 POUND OF AIR AT ATMOSPHERIC PRESSURE 14.7 LBS. PER SQUARE INCH.

Tem- perature	Volume of One Pound.	Tem- perature.	Volume of One Pound	Tem- perature	Volume of One Pound.
Fahr	Cubic Feet.	Fahr	Cubic Feet.	Fahr	Cubic Feet.
0	11.583	230	17.302	325	24.775
32	12.387	240	17.612	550	25.403
40	12.586	250	17.865	575	26.031
50	12.840	260	18.116	600	26.659
62	13.141	270	18.367	670	27.915
70	13.342	280	18.621	700	29.172
80	13.593	290	18.870	750	30.428
90	13.845	300	19.121	800	31.685
100	14.096	320	19.624	850	32.941
120	14.592	340	20.126	900	34.197
140	15.100	360	20.630	950	35.453
160	15.603	380	21.131	1000	36.710
180	16.106	400	21.634	1250	42.990
200	16.606	425	22.262	1500	49.274
210	16.860	450	22.890	2000	61.836
212	16.910	475	23.518	2500	74.400
220	17.111	500	24.146	3000	86.962

TABLE 260.—MELTING POINTS OF ALLOYS OF LEAD, TIN, AND BISMUTH.

	" Fahr.		" Fahr.
1 tin, 5 lead	311	6 tin, 1 lead	381
1 " 3 "	482	4 " 4 " 1 bismuth	326
1 " 2 "	441	2 " 2 " 1 "	292
1 " 1 "	370	1 " 1 " 1 "	254
2 " 1 "	340	5 " 3 " 8 "	202
4 " 1 "	365		

Fine & Plugs.	Soften at	Melt at
	" Fahr.	Fahr.
2 tin 2 lead	315	372
2 " 6 "	370	388
2 " 7 "	377 1/2	388
2 " 8 "	383 1/2	408

TABLE 261.—MELTING POINTS OF METALS.

	° Fahr.		° Fahr.
Aluminium	Ful. red heat	Iron, cast, white.	1928 2012
Antimony	1150	" wrought	2912
Bismuth	507	Lead	61
Bronze	1690	Mercury	—8
Copper	1996	Silver	1870
Gold, standard	2156	Steel	2372
" pure	2282	Tin	256
Iron, cast, gray	2012	Zinc	442 770

TABLE 262.—MELTING POINTS OF SUNDRY SOLIDS.

	° Fahr.		° Fahr.
Carbonic acid	—108	Spermaceti	120
Ice	32	Sulphur	238
Nitro-glycerine	45	Tallow	92
Phosphorus	112	Turpentine	14
Stearine	109 to 120	Wax, rough	142
		" beached	152

TABLE 263 BOILING POINTS OF LIQUIDS, AND HEAT OF EVAPORATION.

Liquid	Boiling Point.	Latent Heat of Evapora- tion of One Pound	Total Heat from 32° F. of One Pound.
	° Fahr.	Units.	Units.
Alcohol	173	374	461.7
Ammonia	140	...	...
Benzine	176	...	...
Linseed oil	597	...	...
Mercury	648	...	...
Sulphuric ether	100	175	210.4
Turpentine	315	134	256.6
Water	212	965.2	1146.1
" sea	213.2	...	...
" saturated brine	228	...	...
Wood spirit	150	475	545.8

power of silver, the best conductor, being 1000, that of mercury is only 54 when the column is vertical, and the source of heat is applied at the upper part of the column. When the column is horizontal, the power is 679. Water, like mercury, presents a complete barrier to conduction of heat applied at the upper end of a vertical column.

TABLE 266. HEAT-CONDUCTING POWER OF ALLOYS AND AMALGAMS. SILVER = 1000.

(F. Grace-Calvert & R. Johnson.)

I. Alloys by which Heat is Conducted in the Ratio of the Calculated Mean Conducting Power of the Metals composing them.

ALLOY	Proportions per Cent., by Weight.	Actual Relative Conducting Power Silver = 1000	Calculated Conducting Power
1. Tin and Lead.			
Pb Sn ^s	T 73.97	385	386
	L 26.03		
Pb Sn	T 36.22	230	236
	L 63.78		
Sn Pb ^s	T 10.20	299	301
	L 89.80		
2. Tin and Zinc.			
Zn ^s Sn	Z 73.43	541	572
	T 26.57		
Zn Sn	Z 35.61	501	495
	T 64.39		
Zn Sn ^s	Z 9.95	456	442
	T 90.05		

II. Alloys containing an Excess of the Worse-Conducting Metal

*3. Lead and Anti-
mony*

Pb Sb	L 61.61	190	251
	A 38.39		
Pb Sb ^s	L 24.30	179	216
	A 75.70		

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (contd.)

ALLOY	Proportions per Cent, by Weight.		Actual Relative Conducting Power Silver=1000.	Calculated Conducting Power.
4. Antimony and Bismuth				
Sb Bi.	A	37.74	62	110
	B	62.26		
Sb Bi ²	A	10.82	48	75
	B	89.18		
5. Copper and Tin.				
Cu Sn	C	34.98	415	558
	T	65.02		
Cu Sn ²	C	21.21	431	504
	T	78.79		
Cu Sn ³	C	15.21	423	481
	T	84.79		
Cu Sn ⁴	C	11.86	406	468
	T	88.14		
Cu Sn ⁵	C	9.73	396	459
	T	90.27		
The following have excess of copper:—				
Sn Cu ²	T	38.21	494	670
	C	61.79		
Sn Cu ⁴	T	31.73	455	686
	C	68.27		
Sn Cu ⁵	T	27.10	207	705
	C	72.90		
6. Zinc and Copper.				
Cu Zn	C	49.32	688	718
	Z	50.68		
Cu Zn ²	C	32.74	428	687
	Z	67.26		
Cu Zn ³	C	24.64	531	672
	Z	75.36		
Cu Zn ⁴	C	19.77	589	663
	Z	80.23		
Cu Zn ⁵	C	16.30	595	857
	Z	83.70		

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*)

ALLOY	Proportions per Cent., by Weight.	Actual Relative Conducting Power. Silver 1000.	Calculated Conducting Power
6. Zinc and Copper (continued). The following have excess of copper —			
Zn Cu ² . . .	Z 33.94 C 66.06	621	748
Zn Cu ³ . . .	Z 25.52 C 74.48	638	764
Zn Cu ⁴ . . .	Z 20.44 C 79.56	666	770
Zn Cu ⁵ . . .	Z 17.05 C 82.95	715	780
7 Commercial Alloys.			
"Yellow brass"	Copper 64.0 Zinc 36.0	558	712
"Pumps and pipes" . . .	Copper 80 Tin 5 Zinc 7.5 Lead 7.5	426	707
"Mud plugs" . . .	Copper 80 Tin 10 Zinc 10	304	784
"Large bear- ings" . . .	Copper 84.05 Tin 12.82 Zinc 6.18	345	751
III. Amalgams (Compounds of Mercury), Solid and Semi-Solid, in which there is an Excess of the Amalgamated Metal.			
8. Amalgams of Tin.			
Hg Sn ² . . .	M 45.88 T 54.12	8.65	8.11
Hg Sn ³ . . .	M 36.18 T 63.82	9.45	9.2
Hg Sn ⁴ . . .	M 29.84 T 70.16	9.65	9.95
Hg Sn ⁵ . . .	M 25.38 T 74.62	10.6	10.5

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (cont.)

ALLOY.	Proportions per Cent., by Weight.	Actual Relative Conducting Power. Silver=1000.	Calculated Conducting Power.
<i>4. Antimony and Bismuth.</i>			
Sb Bi.	A 37.74 B 62.26	62	110
Sb Bi ² .	A 10.82 B 89.18	48	76
<i>5. Copper and Tin.</i>			
Cu Sn	C 34.98 T 65.02	415	558
Cu Sn ²	C 21.21 T 78.79	431	504
Cu Sn ³	C 15.21 T 84.79	423	481
Cu Sn ⁴	C 11.86 T 88.14	406	468
Cu Sn ⁵	C 9.73 T 90.27	396	459
The following have excess of copper:—			
Sn Cu ³	T 38.21 C 61.79	494	670
Sn Cu ⁴	T 31.73 C 68.27	155	686
Sn Cu ⁵	T 27.19 C 72.90	207	705
<i>6. Zinc and Copper.</i>			
Cu Zn	C 49.32 Z 50.68	688	718
Cu Zn ²	C 32.74 Z 67.26	428	687
Cu Zn ³	C 24.64 Z 75.36	531	672
Cu Zn ⁴	C 19.57 Z 80.43	589	663
Cu Zn ⁵	C 16.30 Z 83.70	595	657

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*).

ALLOY	Proportions per Cent., by Weight.	Actual Relative Conducting Power Silver = 1000	Calculated Conducting Power.
6. Zinc and Copper (continued). The following have excess of copper—			
Zn Cu ¹	Z 33.94 C 66.06	621	748
Zn Cu ²	Z 25.52 C 74.48	638	764
Zn Cu ³	Z 20.14 C 79.86	666	770
Zn Cu ⁴	Z 17.05 C 82.95	715	780
7. Commercial Alloys.			
" Yellow brass "	Copper 64.0 Zinc 36.0	559	712
" Pumps and pipes "	Copper 80 Tin 5 Zinc 7.5 Lead 7.5	426	707
" Mud plugs "	Copper 80 Tin 10 Zinc 10	894	784
" Large bear- ings "	Copper 84.05 Tin 12.82 Zinc 5.13	345	751
III. Amalgams (Compounds of Mercury), Solid and Semi-Solid, in which there is an Excess of the Amalgamated Metal			
8 Amalgams of Tin.			
Hg Sn ¹	M 45.88 T 54.12	8.65	8.11
Hg Sn ²	M 36.18 T 63.82	9.45	9.2
Hg Sn ³	M 29.84 T 70.16	9.65	9.95
Hg Sn ⁴	M 25.38 T 74.62	10.6	10.5

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (cont.)

ALLOY	Proportions per Cent., by Weight.	Actual Relative Conducting Power Silver = 1000.	Calculated Conducting Power
9. <i>Amalgams of Zinc.</i>			
Hg Zn ²	M 60.63 Z 39.37	9.7	8.97
Hg Zn ³	M 54.70 Z 45.30	10.45	10.05
Hg Zn ⁴	M 43.50 Z 56.50	11.00	12.08
Hg Zn ⁵	M 38.11 Z 61.89	13.95	13.05
10. <i>Amalgams of Bismuth.</i>			
Hg Bi ²	M 31.82 B 68.18	2.15	1.87
Hg Bi ³	M 23.86 B 76.14	2.6	1.89
Hg Bi ⁴	M 19.03 B 80.97	2.55	1.90
Hg Bi ⁵	M 15.82 B 84.18	2.35	1.91

COMBUSTION — FUELS.

Combustion.

The volume of air consumed chemically in the combustion of fuel is expressed by the formula .—

$$A = 1.52 (C + 3H - \frac{O}{8}) \quad (1)$$

A = volume of air as at 62° F., and under one atmosphere of pressure, in cubic feet, per pound of fuel

A = weight of air as at 62° F. per pound of fuel.

C = percentage of constituent carbon.

H = percentage of constituent hydrogen.

O = percentage of constituent oxygen.

The weight of the air thus found by volume is equal to the volume divided by 13.14. Or it is found directly by the formula—

$$A' = .116 (C + 3H - .4O) . \quad (2)$$

In these formulas the heat evolved by the combustion of the sulphur constituent is not noticed, as it is trifling in proportion.

The volume of the volatile or gaseous products of the complete combustion of one pound of a fuel, as at 62° F., at atmospheric pressure, is, by formula,

$$V = 1.52C + 5.52H \quad (3)$$

The weight of the gaseous products is, by formula, —

$$w = .126C + .358H \quad (4)$$

V = volume of gaseous products, in cubic feet.

w = weight of gaseous products, in pounds.

C = percentage of constituent carbon.

H = percentage of constituent hydrogen.

The volume at any other temperature is found by the formula for expansion of volume of gases, p. 474.

The proportion of free or unconsumed air usually present in the gaseous products is determined by multiplying the percentage of oxygen, found by analysis, by 4.35. The product is the percentage of free air in parts of the whole mixture.

The heat generated by combustion is as follows

Carbon	14,500 heat-units per pound.
Hydrogen	62,000 "
Sulphur	4,000 "

The heating power of fuels containing carbon and hydrogen is approximately expressed by the formula :

$$h = 145 (C + 4.28H) \quad (5)$$

in which h is the total heat of combustion.

The evaporative efficiency for one pound of fuel is

$$e = .15 (C + 4.28H) \quad (6)$$

$$\text{or, } e = \frac{h}{960} \quad (7)$$

e = weight of water evaporated per pound of fuel.

pounds.

The maximum temperature about 5000° F.; and to

Fuels.

Coal consists mainly of carbon, which varies from 50 per cent. to 80 per cent., by weight, of the fuel. Lignite or brown coal contains from 56 to 76 per cent. of carbon. The average composition of British coal is, say, 80 per cent. of carbon, 5 per cent. of hydrogen, $1\frac{1}{2}$ per cent. of sulphur, $1\frac{1}{2}$ per cent. of nitrogen, 8 per cent. of oxygen, and 4 per cent. of ash. The fixed carbon or coke averages 61 per cent. The average specific gravity is 1.279; average weight of a solid cubic foot, 80 pounds; and of a cubic foot heaped, 50 pounds; average bulk of one ton heaped, $44\frac{1}{2}$ cubic feet; equivalent evaporative efficiency, 1540 pounds of water per pound of coal, from and at 212° F.

Bituminous coals hold from 6 per cent. to 10 per cent. of water hygroscopically; Welsh coals from $\frac{1}{2}$ per cent. to $2\frac{1}{2}$ per cent.

Coke contains from 85 to 97 $\frac{1}{2}$ per cent. of carbon, from $\frac{1}{2}$ to 2 per cent. of sulphur, and from $1\frac{1}{2}$ to $14\frac{1}{2}$ per cent. of ash. The average composition may be taken as 93 $\frac{1}{2}$ per cent. of carbon, $1\frac{1}{2}$ per cent. of sulphur; $5\frac{1}{2}$ per cent. of ash. It weighs from 40 lbs. to 50 lbs. per cubic foot solid, and about 30 lbs. broken and heaped. The volume of 1 ton. heaped is from 70 to 80 cubic feet; average, 75 cubic feet. Coke is capable of absorbing from 15 to 20 per cent. of moisture. There is ordinarily from 5 per cent. to 10 per cent. of hygrometric moisture in coke.

Lignite or *brown coal* consists chiefly of carbon, oxygen and nitrogen; averaging in perfect lignite, 69 per cent. of carbon, 5 per cent. of hydrogen, 20 per cent. of oxygen and nitrogen, and 6 per cent. of ash. The weight is about 80 pounds per cubic foot. Imperfect lignite weighs about 72 pounds per cubic foot.

Asphaltic consists, in round numbers, of 79 per cent. of carbon, 9 per cent. of hydrogen, 9 per cent. of oxygen and nitrogen, and 3 per cent. of ash. It weighs about 66 pounds per cubic foot.

Woods of various kinds are approximately the same in composition, averaging, when perfectly dry, 50 per cent. of carbon, 6 per cent. of hydrogen, 41 per cent. of oxygen, 1 per cent. of nitrogen, and 2 per cent. of ash. Green wood when cut down contains moisture to the extent of 45 per cent. of its weight. Wood kept in a dry place holds from 15 per cent. to 20 per cent. of water. In a closely packed pile of wood, consisting of uncloven stems, the interstitial space is about 30 per cent. of the gross bulk. A cord of pine-wood, in the United States of America, is 4 feet by 4 feet by 8 feet, and has a volume of

128 cubic feet. Its weight averages 2,700 pounds, or 21 pounds per cubic foot. A "corde" of wood, in France, has a volume of 4 cubic feet metres or 141 cubic feet. Ordinarily dry wood, in France, averages 20 pounds weight per cubic foot heaped, or 114 cubic feet per ton heaped.

Wood charcoal, as manufactured in the forests, consists of 79 per cent. of carbon, 2 per cent. of free hydrogen, 11 per cent. of hydrogen, oxygen, and nitrogen, and 8 per cent. of ash — average composition. The yield of charcoal varies from 17 to 21 per cent. in weight of the wood, which is a mixture of oak, beech, poplar, willow, and elm. The weight of charcoal as manufactured, heaped, is 14 pounds per cubic foot, in small pieces, heaped, 25 pounds per cubic foot. The bulk of 1 ton heaped is 160 cubic feet and 88.5 cubic feet respectively. Charcoal holds generally 10 or 12 per cent. of moisture.

Peat, cut and dried, has a specific gravity varying from .22 to 1.06. Ordinary air-dried peat holds from 20 per cent. to 30 per cent. of its gross weight of moisture. Perfectly dry peat contains, on an average, 50 per cent. of carbon, 6 per cent. of hydrogen, 30 per cent. of oxygen, $1\frac{1}{2}$ per cent. of nitrogen, and 4 per cent. of ash. The weight of one cubic foot, heaped or stalked, is from 6 pounds to $22\frac{1}{2}$ pounds per cubic foot; or, the volume of one ton is from 370 cubic feet to 100 cubic feet. Condensed peat, such as is macerated and mixed, weighs from 44 to 57 pounds per cubic foot stalked, or the volume is from 51 to 40 cubic feet per ton.

Peat charcoal is yielded at the rate of from 30 per cent. to 40 per cent. by weight of good peat. It contains from 85 to 90 per cent. of carbon, and from 10 to 15 per cent. of ash.

Straw, in its ordinary state, consists of about 16 per cent. of water, 36 per cent. of carbon, 5 per cent. of hydrogen, 38 per cent. of oxygen, $\frac{1}{4}$ per cent. of nitrogen, and $4\frac{1}{2}$ per cent. of ash. Pressed straw weighs from 6 pounds to 8 pounds per cubic foot.

Petroleum consists of about 85 per cent. of carbon, 13 per cent. of hydrogen, and 2 per cent. of oxygen; having .87 specific gravity, and weighing 8.70 pounds per gallon. *Petroleum oils* consist of about 73 per cent. of carbon, and 27 per cent. of hydrogen; having .71 specific gravity, and weighing 7.10 pounds per gallon.

Coal Gas, which will be noticed in detail, consists, in round numbers, of 12 per cent. of elefant gas, 53 per cent. of marsh gas, 14 per cent. of carbonic oxide, 8 per cent. of hydrogen, 6 per cent. of nitrogen, and a small fraction of oxygen.

For the above-named fuels, the Heat of Combustion is recorded in Table 267, with the quantity of air chemically consumed.

TABLE 267. HEAT OF COMBUSTION OF FUELS.

Fuel.	Air Chemically Consumed per Pound of Fuel.		Total Heat of Combustion of One Pound of Fuel.	Equivalent Evaporative Power, from and at 212° F., Water per Pound of Fuel.
	Pounds.	Cub. Ft. at 62° F.	Units.	Pounds.
Coal of average composition	10.7	140	14,700	15.22
Coke	10.81	142	13,548	14.02
Lignite	8.83	116	13,108	13.57
Asphalts	11.85	156	17,040	17.64
Wood, desiccated	6.09	80	10,974	11.36
Wood, 25 per cent. moisture	4.57	60	7,951	8.20
Wood charcoal, desiccated	9.51	125	13,006	13.46
Peat, desiccated	7.52	99	12,279	12.71
Peat, 30 per cent. moisture	5.24	69	8,260	8.53
Peat charcoal, desiccated	9.9	130	12,325	12.76
Straw	4.26	56	8,144	8.43
Petroleum	14.33	188	20,411	21.13
Petroleum oils	17.93	235	27,531	28.50
Coal gas, per cubic foot at 62° F. . . . .	..	..	630	.70

WARMING AND VENTILATION.—COOKING-STOVES.

Warming and Ventilation.

The quantity of air required for ventilation of buildings is variously estimated at from 3½ cubic feet to 20 cubic feet per minute, or from 210 to 1,200 cubic feet per hour per head of inmates in ordinary good health. In public schools, 1,800 cubic feet per hour per head is recommended, for

theatres and concert-halls, from 1,500 to 3,000 cubic feet; for hospitals, from 4,000 to 6,000 cubic feet. For each lamp or gas-burner employed, from 30 to 60 cubic feet per hour should be provided.

In warming dwelling-rooms by open coal fires and by close stoves, the results of the tests made by Mr. D. K. Clark for the Smoke Abatement Committee, showed that the heat of combustion was distributed as follows:—

	Open Grates.	Close Stoves.
Heat carried up the chimney	43	24
Radiated and conducted heat absorbed by the walls	42	54
Heat lost by radiation and conduction externally, and heat lost by imperfection of combustion	15	22
	<hr/> 100	<hr/> 100

The grates and stoves were tested in rooms 15 feet square, 17 feet total height; having 3,600 cubic feet of capacity.

	Open Grates.	Close Stoves.
Average weight of Wallsend coal consumed per hour	3·65 lbs.	3·87 lbs.
Average rise of temperature maintained in the room	10·83° F.	17·74° F.
Average rise of temperature maintained per lb. of coal consumed per hour	3·22° F.	4·48° F.

It was shown that, of the open grates, those constructed on the principle of drawing the combustible gases through the incandescent fuel, were the most efficient, and that, of these, the best were those in which the fresh fuel was supplied below the fire, the combustible gases rising upwards through it. Ordinary open fires, having either bottom grids or solid floors, were the least effective for warming relatively to the quantity of coal consumed per hour.

The efficiency generally varied inversely as the depth of the smoke-stack at the top of the chimney.

The velocity and temperature of draught in the chimney, which was 8½ inches in diameter, were as follows:—

	Open Grates.	Close Stoves.
Velocity of draught in feet per minute	875 ft.	275 ft.

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*)

Alloy.	Proportions per Cent., by Weight.		Actual Relative Conducting Power Silver=1000.	Calculated Conducting Power
4. Antimony and Bismuth.				
Sb Bi.	A	37.74	62	110
	B	62.26		
Sb Bi ²	A	10.82	48	75
	B	89.18		
5. Copper and Tin				
Cu Sn	C	34.98	415	558
	T	65.02		
Cu Sn ²	C	21.21	431	504
	T	78.79		
Cu Sn ³	C	15.21	423	481
	T	84.79		
Cu Sn ⁴	C	11.86	406	468
	T	88.14		
Cu Sn ⁵	C	9.73	396	439
	T	90.27		
The following have excess of copper. —				
Sn Cu ²	T	38.21	494	670
	C	61.79		
Sn Cu ⁴	T	31.73	155	686
	C	68.27		
Sn Cu ⁵	T	27.10	207	705
	C	72.90		
6. Zinc and Copper.				
Cu Zn	C	49.32	688	718
	Z	50.68		
Cu Zn ²	C	32.74	428	687
	Z	67.26		
Cu Zn ³	C	24.64	531	672
	Z	75.36		
Cu Zn ⁴	C	19.57	589	693
	Z	80.43		
Cu Zn ⁵	C	16.30	595	657
	Z	83.70		

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*)

ALLOY	Proportions per Cent., by Weight.	Actual Relative Conducting Power Silver = 1000.	Calculated Conducting Power
6. <i>Zinc and Copper</i> (<i>continued</i>). The following have excess of copper:—			
Zn Cu ² . . .	Z 33.94 C 66.06	621	748
Zn Cu ³ . . .	Z 25.52 C 74.48	638	764
Zn Cu ⁴ . . .	Z 20.44 C 79.56	666	770
Zn Cu ⁵ . . .	Z 17.05 C 82.95	715	780

7. *Commercial Alloys.*

" Yellow brass "	Copper	64.0	558	712
	Zinc	36.0		
" Pumps and pipes "	Copper	80	426	707
	Tin	5		
	Zinc	7.5		
	Lead	7.5		
" Mud plugs "	Copper	80	804	764
	Tin	10		
	Zinc	10		
" Large bear- ings "	Copper	84.05	345	751
	Tin	12.82		
	Zinc	5.13		

III. *Amalgams (Compounds of Mercury), Solid and Semi-Solid, in which there is an Excess of the Amalgamated Metal.*8. *Amalgams of Tin.*

Hg Sn ² . . .	M	45.88	8.65	8.11
	T	54.12		
Hg Sn ³ . . .	M	36.18	9.45	9.2
	T	63.82		
Hg Sn ⁴ . . .	M	29.84	9.65	9.95
	T	70.16		
Hg Sn ⁵ . . .	M	25.88	10.6	10.5
	T	74.62		

Building.	Temperature Required	Length Feet
Public buildings	55	6
Workshops, warehouses, &c	55	6
Schools, churches, offices, bed- rooms, &c.	60	7
Shops, waiting rooms, &c.	60	10
Living rooms	65	10
Drying stoves (closed rooms)	100	10
" "	110	12
" "	120	17
" "	130	20
Conservatories, greenhouses, &c	45 to 50	20
Pneries, &c	50 to 55	40
Vineries, stoves	55 to 60	40
" "	60 to 65	50
Orchids, stoves	65 to 70	50
" "	70 to 75	60
Pineries, forcing houses	75 to 80	70

Distribution of Heat in Furnaces.

In melting pig-iron in an ordinary cupola by the combustion of 30 per cent. of its weight of coke, Peclet estimated that 14 per cent. only of the heat of combustion was actually utilised.

In an ordinary metallurgical re-heating furnace, one ton of coal is consumed in heating 14 tons of wrought-iron to the welding point, 2,700° F., showing that only 4 per cent. of the whole heat generated is appropriated by the metal.

Barely 1½ per cent. of the whole heat generated is absorbed in melting pot steel in ordinary furnaces. In the Siemens regenerative furnace, a ton of steel is melted for the combustion of 12 cwt. of small coal, showing that 6 per cent. of the heat produced is utilised.

Sir I. Lowthian Bell's estimate of the distribution of heat in a blast furnace from Durham coke, which contains 92.5 per cent. of carbon, for the production of 1 ton of pig-iron is as follows—He assumes that 30.4 per cent. of the carbon of the fuel—Durham coke—which escapes in a gaseous form, is carbonic acid; and that, therefore, only 51.27 per cent. of the heating power of the fuel is developed, and the remaining 48.73 per cent. leaves the tunnel head undeveloped. He adopts as a unit of heat, the heat required to raise the temperature of 112 pounds of water 1° centigrade. To produce 1 ton of pig-iron there are required 11 cwt. of limestone and 49 cwt. of calcined ironstone. The ironstone consists of 18.6 cwt. of iron, 9 cwt. of oxygen, and 21.4 cwt. of earths.

For 1 ton of Pig-Iron.

	Units.	Percent.
Evaporation of water in coke and chemical action in smelting	48,354	54.1
Fusion of pig-iron	6,600	7.4
Fusion of slag	15,356	17.2
Expansion of blast	3,700	4.1
For direct work of furnace	74,010	82.8
Loss by radiation through the walls	3,600	
Carried away by tuyere water	1,800	
Sensible heat of gaseous products	10,000	
Waste	15,400	17.2
Total heat generated in the furnace	89,410	100.0

Gas-Heating Stoves and Fires.

The results of Mr. D. K. Clark's test-trials of Gas-Heating Stoves and Fires of various classes, are summarized in Table 270.

TABLE 270.—AVERAGE RESULTS OF TEST-TRIALS OF GAS-HEATING STOVES AND FIRES.

Classes of Stoves.	Ex- ternal Tem- pera- ture.	Tem- pera- ture in the Test- ing Room.	Dif- ference, or Ele- vation of Tem- pera- ture.	Gas Con- sumed per Hour.	Gas per Hour per Degree of Ele- vation of Tem- perature.	Room Space per Cubic Foot of Gas per Hour per Degree of Eleva- tion of Tem- perature.
I. Close stoves	57.1	64.9	7.8	10.9	1.06	215
II. Open stoves :—						
Asbestos fuel stoves	57.4	72.1	14.7	28.7	2.06	175
Tile stoves	59.7	69.2	9.5	16.9	1.64	193
III. Gas baskets or gas fires :						
Reflector stoves	58.7	66.5	7.8	11.1	1.55	237
Gas fires	55.8	63.7	7.9	12.2	1.57	229

The volume of the testing-room was about 3,600 cubic feet. The consumption of gas per hour per degree of elevation of temperature is the measure of relative effectiveness: showing that the reflector stoves were the most effective, consuming about $1\frac{1}{2}$ cubic feet of gas per hour per degree. Gas baskets, or gas fires, were practically of equal efficiency with the reflector stoves. Next in order, are close stoves, then tile stoves; and, lastly, asbestos fuel stoves, consuming 2 cubic feet of gas per hour per degree.

The ventilation of the room, as dependent on draught in the chimney, averaged from 6,000 to 10,000 cubic feet of air, as at 62° F., per hour: showing that a volume of air of from twice to thrice the capacity of the room, was passed up the chimney per hour. By the natural draught in the chimney independent of the augmentation of draught by the stove heat, 2,400 cubic feet of air passed up the chimney per hour.

The average efficiency of the stoves was upwards of 90 per cent., or, less than 10 per cent. of the heat generated was wasted up the chimney.

Cooking Ranges.

From the average results of tests of Cooking Ranges at the Smoke Abatement Exhibition, it appears that a joint from the loin weighing $12\frac{1}{2}$ lbs., and a sample of puff pastry following

the joint, were roasted and baked in two hours, with a consumption of 17 pounds of hard steam coal.

Cooking with Gas.*

From the average results of numerous test-trials of gas-cooking stoves, having burners inside, in roasting legs of mutton weighing from 8 lbs. to 9 lbs. each, the loss of weight and net weight were as follows:—

Average distribution of Joints when very well done.

Joint as cooked	6 lbs. 7 oz. or	77 per cent.
Dripping	1 " 0 " "	12 " "
Loss by evaporation	0 " 15 " "	11 " "

8 lbs. 6 oz. or 100 per cent.

The bone of a leg of mutton weighed 1 pound.

The average temperature in the oven was 378° F. The average length of time roasting was 2 hours 16 minutes; or at the rate of a quarter of an hour per pound weight of the joint, with 16 minutes for the odd 6 ounces. The average quantity of gas consumed while roasting was 22·6 cubic feet of the average temperature 56° F., or at the rate of 2·70 cubic feet per pound of fresh joint, and of 10 cubic feet per hour. Adding the gas consumed in heating up the stoves, which was an average of 3·40 cubic feet, the sum is 26 cubic feet of gas; the total average consumption being at the rate of 3·1 cubic feet per pound of the fresh joint. The average capacity of the ovens was 2·54 cubic feet, represented nearly by that of Davis's No. 9 Stove, which is 22 inches high above the burners, and 14½ inches square. The flavour of the meat roasted by plain gas was decidedly better than that of the meat roasted by atmospheric gas.

Externally heated stoves consumed about one-third more gas than internally heated stoves.

The distribution of the heat of combustion of the 22 cubic feet of gas consumed in roasting the joint, averaging for 25 trials, was as follows

	Heat Units.	Gas.	Cubic Feet at 62° F.	Per cent.
Roasting the joint	2,203	or	3·54	or 16·1
Carried off in the burnt gases	585	"	0·94	" 4·3
Dispersed by external radiation and conduc- tion	10,896	"	17·52	" 79·6
	13,684	"	22·0	" 100·0

Showing that barely one-sixth of the whole of the heat

* See *International Electric and Gas Exhibition, 1882-83: Report on the Gas Section*, by D. K. Clark.

generated was utilised in roasting; that the proportion of heat carried off in the burnt gases was comparatively insignificant, and that four-fifths of the total heat was dispersed wastefully.

STEAM.

The leading properties of saturated steam are stated in Table 271 (p. 498). The specific heat of saturated steam is .305 at constant volume. That of steam gas is .3648 at constant volume, and .475 at constant pressure.

Steam of from 25 lbs. to 215 lbs. absolute pressure flows into the atmosphere, at a velocity averaging about 900 feet per second, as calculated for constant density,—that is to say, on the assumption that the steam does not expand in the course of the outflow. It actually expands and attains a velocity by expansion averaging 1450 feet per second.

Equivalent Weight of Steam formed from and at 212° F.—Let w = the weight of water evaporated per pound of a fuel, from water supplied at the temperature t , into steam of the total heat H , measured from 32° F. Let w' , t' , and H' , be the corresponding values for steam of any other pressure. Then the total heat expended in evaporating 1 pound of water is $H + 32 - t$, or $H' + 32 - t'$; and

$$w' = w \frac{H + 32 - t}{H' + 32 - t'} \quad . \quad . \quad . \quad . \quad (1)$$

Let H' be the total heat of steam generated at 212° F., or 1146 units; and $t' = 212^\circ$ E. By substitution and reduction,

$$w' = w \frac{H + 32 - t}{966} \quad . \quad . \quad . \quad . \quad (2)$$

in which w' is the equivalent weight of water evaporated from and at 212° F.

RULE.—*To find the equivalent weight of water evaporated from and at 212° F., when a given weight of water is supplied at a given temperature, and evaporated under a given pressure.*—Find in Table 271, the total heat of the steam generated at the given absolute pressure; add 32 to it, and from the sum subtract the temperature of the feed-water; divide the remainder by 966, and multiply the quotient by the given weight of water. The product is the equivalent weight of water as evaporated from and at 212° F.

Moisture or Priming in Steam.

Blow a quantity of the so-called steam into a vessel holding

a given weight of cold water : noting the pressure and the weight of the steam blown in, and the initial and final temperatures of the mixture. An addition is to be made to the initial weight of water, to represent the weight of water equivalent to that of the vessel containing the water, in terms of their respective specific heats. A corresponding addition is to be made for such portion of the apparatus as is immersed in the water.

Let W = weight of condensing water, plus the equivalent weight of the receiver and apparatus immersed in the water.

w = weight of nominal steam discharged into the vessel under water.

$W + w$ = gross weight of mixture of nominal steam and condensing water.

H = total heat of one pound of the steam, reckoned from the temperature of the condensing water.

Hw = total heat delivered by the gross weight of nominal steam discharged, taken as dry steam.

t = initial temperature of condensing water.

t' = final do. do. do.

s = augmentation of specific heat of water due to rise of temperature.

L = latent heat of one pound of steam of the given initial pressure.

Lw = latent heat of steam discharged into the vessel, taking it as dry steam.

P = weight of priming or moisture in percentage of the gross weight of nominal steam.

$$P = 100 \frac{Hw - [(W + w) \times (t' - t + s)]}{Lw} \quad (3)$$

RULE. *To determine the proportion of moisture or priming in steam.*—To the rise of temperature add the augmentation of specific heat of the water. Multiply the gross weight of nominal steam and condensing water by this sum, and deduct the product from the constituent or total heat of the weight discharged into the vessel, taken as dry steam; and reckoned from the temperature of the condensing water. Multiply the remainder by 100, and divide by the latent heat of the steam taken as dry. The quotient is the proportion of water in percentage of the gross weight of nominal steam.

If there be no remainder, the steam is taken as dry. If, on the contrary, the product be greater than the constituent heat, the difference is evidence of superheated steam, the percentage of which is found by dividing the difference by the latent heat of the steam taken as dry.

TABLE 271.—SATURATED STEAM.

Absol- ute Pres- sure per Square Inch.	Tem- pera- tures	Total Latent Heat of Steam from Water sat- urated at 32° F.	Water Heat of Steam raise Tem- pera- ture of Water from 32° F.	Total Heat of One Pound of Steam from Water sat- urated at 32° F.	Density or Weight of One Cubic Foot of Steam.	Volume of One Pound of Steam.
1	2	3	4	5	6	7
Feet.	Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.
0.5	80.2	1028.4	47.1	1105.5	.001376	726.608
1	102.1	1042.9	69.6	1112.5	.003027	330.360
1.5	115.9	1033.2	83.5	1116.7	.004433	225.580
2	126.5	1027.8	93.9	1119.7	.005811	172.080
2.5	134.6	1019.4	102.6	1122.5	.007169	139.488
3	141.6	1015.4	109.6	1124.6	.008511	117.500
3.5	147.7	1010.0	115.8	1126.4	.009839	101.632
4	153.1	1006.8	121.3	1128.1	.01116	89.632
4.5	157.9	1003.4	126.2	1129.6	.01246	80.233
5	162.3	1000.3	130.6	1130.9	.01370	72.994
5.5	166.4	997.4	134.7	1132.1	.01505	66.428
6	170.2	994.7	138.6	1133.3	.01634	61.204
6.5	173.6	992.3	142.0	1134.3	.01762	56.761
7	176.9	990.0	145.3	1135.3	.01889	52.936
7.5	180.0	987.8	148.5	1136.3	.02016	49.610
8	182.9	985.7	151.5	1137.2	.02142	46.686
8.5	185.7	983.8	154.2	1138.0	.02268	44.097
9	188.3	981.9	156.9	1138.8	.02394	41.777
9.5	190.8	980.1	159.4	1139.5	.02517	39.261
10	193.3	978.4	161.9	1140.3	.02642	37.845
10.5	195.6	976.7	164.3	1141.0	.02767	36.145
11	197.8	975.2	166.5	1141.7	.02890	34.599
11.5	200.1	973.6	168.8	1142.4	.03026	33.045
12	202.0	972.2	170.8	1143.0	.03137	31.879
12.5	204.0	970.8	172.8	1143.6	.03260	30.678
13	205.9	969.4	174.8	1144.2	.03382	29.573
13.5	207.8	968.1	176.7	1144.8	.03504	28.536
14	209.6	966.8	178.5	1145.3	.03627	27.573
14.7	212.0	965.2	180.9	1146.1	.03797	26.360
15	213.1	964.3	182.1	1146.4	.03870	25.843
16	216.3	962.1	185.3	1147.4	.04112	24.326
17	219.6	959.8	188.5	1148.3	.04253	23.515
18	222.4	957.7	191.5	1149.2	.04594	21.78
19	225.3	955.7	194.4	1150.1	.04834	20.6

TABLE 271 SATURATED STEAM (continued).

Tem- peratures.	Total Latent Heat of Steam from Water sup- plied at 32° F.	Water heat of steam to raise Tem- per- ature of Water from 32° F.	Total Heat of the Pound of Steam from Water supplied at 32° F.	Density, or Weight of One Cubic Foot of Steam	Volume of One Pound of Steam	Relative Volume, or the feet of Steam from One Cubic Foot of Water
° Fahr.	Lb.-ft.	Lb.-ft.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
228.0	953.8	197.1	1150.9	.05074	19.710	1229.0
230.6	951.9	199.8	1151.7	.05311	18.828	1174.0
233.1	950.2	202.4	1152.5	.05549	18.022	1123.8
235.5	948.7	204.7	1153.3	.05786	17.282	1077.6
237.8	946.9	207.0	1153.9	.06023	16.603	1035.2
240.1	945.3	209.3	1154.6	.06259	15.977	996.2
242.3	943.7	211.6	1155.3	.06495	15.461	960.2
244.4	942.2	213.6	1155.8	.06728	14.863	926.8
246.4	940.8	215.6	1156.4	.06971	14.345	894.5
248.4	939.4	217.7	1157.1	.07196	13.896	866.5
250.4	937.9	219.9	1157.8	.07430	13.459	839.2
252.2	936.7	221.7	1158.4	.07663	13.050	813.7
254.1	935.3	223.6	1158.9	.07894	12.666	789.8
255.9	934.0	225.5	1159.5	.08128	12.306	767.1
257.6	932.8	227.2	1160.0	.08358	11.964	746.0
259.3	931.6	228.9	1160.5	.08590	11.640	725.9
260.9	930.5	230.5	1161.0	.08821	11.337	706.9
262.6	929.3	232.2	1161.5	.09050	11.050	689.0
264.2	928.2	233.8	1162.0	.09282	10.773	671.7
265.8	927.1	235.4	1162.5	.09510	10.515	655.6
267.3	926.0	236.9	1162.9	.09740	10.267	640.2
268.7	924.9	238.5	1163.4	.09946	10.054	626.9
270.2	923.9	239.9	1163.8	.1020	9.806	614.4
271.6	922.9	241.3	1164.2	.1042	9.592	598.1
273.0	921.9	242.7	1164.6	.1065	9.386	585.3
274.4	920.9	244.2	1165.1	.1088	9.191	573.1
275.8	919.9	245.6	1165.5	.1111	9.003	561.4
277.1	919.0	246.9	1165.9	.1134	8.821	550.0
278.4	918.1	248.2	1166.3	.1156	8.650	539.8
279.7	917.2	249.5	1166.7	.1179	8.482	529.9
281.0	916.3	250.8	1167.1	.1202	8.322	520.9
282.3	915.4	252.1	1167.5	.1224	8.170	513.4
283.5	914.5	253.1	1167.9	.1247	8.021	506.2
284.7	913.6	254.7	1168.3	.1269	7.880	499.4

TABLE 271.—SATURATED STEAM (continued).

Absol- ute Pres- sure per Square Inch	Tem- per- ature	Total Latent Heat of Steam from Water sup- plied at 32° F.	Water- out of Steam (to raise Tem- pera- ture of Water from 32° F.)	Total Heat of One Pound of Steam from Water supplied at 32° F.	Density, or Weight of One Cubic Foot of Steam	Volume of One Pound of Steam	Heat of Evapora- tion from the Table Foot of Water.
1	2	3	4	5	6	7	8
Lbs.	Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Heat Vt.
54	285.9	912.8	255.8	1168.6	1292	7.741	482.7
55	287.1	912.0	257.0	1169.0	1314	7.610	474.5
56	288.2	911.2	258.1	1169.3	1337	7.482	466.8
57	289.3	910.4	259.3	1169.7	1357	7.370	459.3
58	290.4	909.6	260.4	1170.0	1382	7.238	451.3
59	291.6	908.8	261.6	1170.4	1404	7.123	444.2
60	292.7	908.0	262.7	1170.7	1426	7.011	437.2
61	293.8	907.2	263.9	1171.1	1449	6.902	430.4
62	294.8	906.4	265.0	1171.4	1471	6.798	423.9
63	295.9	905.6	266.1	1171.7	1493	6.696	417.5
64	296.9	904.9	267.1	1172.0	1516	6.596	411.3
65	298.0	904.2	268.1	1172.3	1538	6.502	405.4
66	299.0	903.5	269.1	1172.6	1560	6.410	399.7
67	300.0	902.8	270.1	1172.9	1583	6.318	394.0
68	300.9	902.1	271.1	1173.2	1604	6.233	388.7
69	301.9	901.4	272.1	1173.5	1627	6.147	383.3
70	302.9	900.8	273.0	1173.8	1650	6.059	377.8
71	303.9	900.3	273.8	1174.1	1671	5.984	373.1
72	304.8	899.6	274.7	1174.3	1693	5.905	368.2
73	305.7	898.9	275.7	1174.6	1716	5.829	363.6
74	306.6	898.2	276.7	1174.9	1738	5.754	358.8
75	307.5	897.5	277.7	1175.2	1760	5.683	354.4
76	308.4	896.8	278.6	1175.4	1782	5.610	349.8
77	309.3	896.1	279.6	1175.7	1803	5.544	345.7
78	310.2	895.5	280.5	1176.0	1826	5.476	341.5
79	311.1	894.9	281.4	1176.3	1848	5.411	337.4
80	312.0	894.3	282.2	1176.5	1870	5.348	333.5
81	312.8	893.7	283.1	1176.8	1892	5.286	329.6
82	313.6	893.1	284.0	1177.1	1912	5.230	326.1
83	314.5	892.5	284.9	1177.4	1936	5.167	322.2
84	315.3	892.0	285.6	1177.6	1957	5.109	318.5
85	316.1	891.4	286.5	1177.9	1980	5.052	315.0
86	316.9	890.8	287.3	1178.1	2001	4.996	311.2
87	317.8	890.2	288.2	1178.4	2023	4.942	307.6

TABLE 271 - SATURATED STEAM (continued)

Absolute Pressure per Square Inch.	Temperatures.	Total Latent Heat of Steam from Water supplied at 32° F.	Water heat of Steam (to raise Temperature of Water from 32° F.).	Total Heat of One Pound of Steam from Water supplied at 32° F.	Density, or Weight of One Cubic Foot of Steam.	Volume of One Pound of Steam.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water.
1	2	3	4	5	6	7	8
Lbs.	Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. vol.
88	318.6	889.6	289.0	1178.6	.2046	4.889	304.8
89	319.4	889.0	289.9	1178.9	.2067	4.837	301.6
90	320.2	888.5	290.6	1179.1	.2088	4.790	298.6
91	321.0	887.9	291.4	1179.3	.2111	4.737	295.4
92	321.7	887.3	292.2	1179.5	.2133	4.688	292.3
93	322.5	886.8	293.0	1179.8	.2154	4.642	289.4
94	323.3	886.3	293.7	1180.0	.2176	4.595	286.5
95	324.1	885.8	294.5	1180.3	.2198	4.549	283.7
96	324.8	885.2	295.3	1180.5	.2220	4.505	280.9
97	325.6	884.6	296.2	1180.8	.2241	4.462	278.2
98	326.3	884.1	296.9	1181.0	.2263	4.419	275.5
99	327.1	883.6	297.6	1181.2	.2286	4.375	272.8
100	327.9	883.1	298.3	1181.4	.2307	4.335	270.3
101	328.5	882.6	299.0	1181.6	.2329	4.305	267.8
102	329.4	882.1	299.7	1181.8	.2350	4.256	265.4
103	329.9	881.6	300.4	1182.0	.2372	4.216	262.9
104	330.6	881.1	301.1	1182.2	.2393	4.178	260.5
105	331.3	880.7	301.7	1182.4	.2415	4.140	258.2
106	331.9	880.2	302.4	1182.6	.2437	4.104	255.9
107	332.6	879.7	303.1	1182.8	.2458	4.068	253.6
108	333.3	879.2	303.8	1183.0	.2480	4.033	251.4
109	334.0	878.7	304.6	1183.3	.2502	3.998	249.3
110	334.6	878.3	305.2	1183.5	.2523	3.963	247.1
111	335.3	877.8	305.9	1183.7	.2545	3.930	245.0
112	336.0	877.3	306.6	1183.9	.2566	3.897	243.0
113	336.7	876.8	307.3	1184.1	.2588	3.865	241.0
114	337.4	876.3	308.0	1184.3	.2610	3.832	238.9
115	338.0	875.9	308.6	1184.5	.2631	3.801	237.0
116	338.6	875.5	309.2	1184.7	.2653	3.770	235.0
117	339.3	875.0	309.9	1184.9	.2674	3.740	233.2
118	339.9	874.5	310.6	1185.1	.2696	3.710	231.8
119	340.5	874.1	311.2	1185.3	.2717	3.681	229.5
120	341.1	873.7	311.7	1185.4	.2738	3.652	227.5
121	341.8	873.2	312.4	1185.6	.2760	3.623	225.5

TABLE 271.—SATURATED STEAM (*continued*).

Absolute Pressure per Square Inch.	Temperatures.	Total Latent Heat of Steam from Water supplied at 32° F.	Water heat of Steam (to raise Temperature of Water from 32° F.).	Total Heat of One Pound of Steam from Water supplied at 32° F.	Density, or Weight of One Cubic Foot of Steam.	Volume of One Pound of Steam.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water.
1.	2.	3.	7.	8.	8.	9.	10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
54	285.9	912.8	255.8	1168.6	.1292	7.741	482.7
55	287.1	912.0	257.0	1169.0	.1314	7.610	474.5
56	288.2	911.2	258.1	1169.3	.1337	7.482	466.5
57	289.3	910.4	259.3	1169.7	.1357	7.370	459.5
58	290.4	909.6	260.4	1170.0	.1382	7.288	451.3
59	291.6	908.8	261.6	1170.4	.1404	7.123	444.2
60	292.7	908.0	262.7	1170.7	.1426	7.011	437.2
61	293.8	907.2	263.9	1171.1	.1449	6.902	430.4
62	294.8	906.4	265.0	1171.4	.1471	6.798	423.9
63	295.9	905.6	266.1	1171.7	.1493	6.696	417.5
64	296.9	904.9	267.1	1172.0	.1516	6.596	411.3
65	298.0	904.2	268.1	1172.3	.1538	6.502	405.4
66	299.0	903.5	269.1	1172.6	.1560	6.410	399.7
67	300.0	902.8	270.1	1172.9	.1583	6.318	394.0
68	300.9	902.1	271.1	1173.2	.1604	6.233	388.7
69	301.9	901.4	272.1	1173.5	.1627	6.147	383.3
70	302.9	900.8	273.0	1173.8	.1650	6.059	377.8
71	303.9	900.3	273.8	1174.1	.1671	5.984	373.1
72	304.8	899.6	274.7	1174.3	.1693	5.905	368.2
73	305.7	898.9	275.7	1174.6	.1716	5.829	363.5
74	306.6	898.2	276.7	1174.9	.1738	5.754	358.8
75	307.5	897.5	277.7	1175.2	.1760	5.683	354.4
76	308.4	896.8	278.6	1175.4	.1782	5.610	349.8
77	309.3	896.1	279.6	1175.7	.1803	5.544	345.7
78	310.2	895.5	280.5	1176.0	.1826	5.476	341.5
79	311.1	894.9	281.4	1176.3	.1848	5.411	337.4
80	312.0	894.3	282.2	1176.5	.1870	5.348	333.5
81	312.8	893.7	283.1	1176.8	.1892	5.286	329.6
82	313.6	893.1	284.0	1177.1	.1912	5.230	326.1
83	314.5	892.5	284.9	1177.4	.1936	5.167	322.2
84	315.3	892.0	285.6	1177.6	.1957	5.109	318.5
85	316.1	891.4	286.5	1177.9	.1980	5.052	315.0
86	316.9	890.8	287.3	1178.1	.2001	4.996	311.5
87	317.8	890.2	288.2	1178.4	.2023	4.942	308.2

TABLE 271 SATURATED STEAM (continued).

Tem- pera- tures.	Total Latent Heat of Steam from Water sup- plied at 2° F	Water Heat of Steam to raise Tem- pera- ture of Water from 32° F	Total Heat of One Pound of Steam from Water supplied at 32° F	Density, or Weight of One Cubic Foot of Steam	Volume of One Pound of Steam.	Relative Volume or Cubic Feet of Steam from One Cubic Foot of Water
6.	7.	8.	9.	10.	11.	12.
* Fahr	Units	Units.	Faths.	Lbs.	Cub. Ft.	Rel. Vol.
361.6	859.2	332.5	1191.7	3505	2.853	177.9
362.1	858.0	332.9	1191.8	3527	2.836	176.8
362.6	857.5	333.5	1192.0	3548	2.818	175.7
363.1	856.1	334.0	1192.1	3569	2.802	174.7
363.5	855.8	334.5	1192.3	3590	2.785	173.7
366.0	856.2	336.7	1192.9	3696	2.706	168.7
368.2	854.5	339.2	1193.7	3801	2.631	164.1
370.8	852.9	341.5	1194.4	3905	2.559	159.7
372.9	851.3	343.8	1195.1	4011	2.493	155.5
375.3	849.6	346.2	1195.8	4115	2.430	151.6
377.5	848.0	348.5	1196.5	4220	2.370	147.8
379.7	846.5	350.7	1197.2	4324	2.313	144.2
381.7	845.0	352.8	1197.8	4419	2.263	141.1

STEAM ENGINES AND BOILERS.

Steam Engines.

Work of steam in the cylinder is in two parts:—the work of admission, and the work done during expansion after steam is cut off.

Absolute work done during admission is,

$$p_1 V_1 \text{ or } p(V' - C) \quad (1)$$

Absolute work done during expansion to the end of the stroke is

$$p_1 V_1 + \text{hyp. log } R' \quad (2)$$

For purposes of calculation, the hyperbolic law of expansion is assumed; according to which the pressure varies inversely as the volume.

Sum for these two quantities gives the total absolute

TABLE 271. SATURATED STEAM (continued).

Absol- ute Pres- sure per Square Inch.	Tem- pera- tures.	Total Latent Heat of Steam from Water saturated at 32° F.	Water- heat of Steam to raise Tem- perature of Water from 32° F.	Total Heat of One Pound of Steam from Water supplied at 32° F.	Density, or Weight of One Cubic Foot of Steam.	Volume of One Pound of Steam.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water.
1	2	3	4	5	6	7	8
119	Fahr.	Units.	Units.	Units.	Lbs.	Cu. ft.	Rel. Vol.
122	342.4	872.8	317.0	1185.8	2781	3.595	224.2
123	343.0	872.3	313.7	1186.0	2803	3.567	222.4
124	343.6	871.9	311.3	1186.2	2824	3.541	220.8
125	344.2	871	311.9	1186.4	2846	3.514	219.1
126	344.8	871.1	311.5	1186.6	2867	3.488	217.5
127	345.4	870.7	311.1	1186.8	2889	3.462	215.8
128	346.0	870.2	310.7	1186.9	2911	3.436	214.3
129	346.6	869.8	317.3	1187.1	2931	3.411	212.7
130	347.2	869.4	317.9	1187.3	2951	3.388	211.3
131	347.8	869.0	318.5	1187.5	2974	3.362	209.7
132	348.3	868.6	319.0	1187.6	2996	3.338	208.1
133	348.9	868.2	319.6	1187.8	3017	3.315	206.7
134	349.5	867.8	320.2	1188.0	3038	3.291	205.2
135	350.1	867.4	320.8	1188.2	3060	3.268	203.8
136	350.6	867	321.3	1188.3	3080	3.246	202.4
137	351.2	866.6	321.9	1188.5	3102	3.224	201.0
138	351.8	866.2	322.5	1188.7	3123	3.201	199.6
139	352.4	865.8	323.1	1188.9	3145	3.180	198.3
140	352.9	865.4	323.6	1189.0	3166	3.159	197.0
141	353.5	865.0	324.2	1189.2	3187	3.138	195.6
142	354.0	864.6	324.8	1189.4	3209	3.117	194.3
143	354.5	864.2	325.4	1189.6	3230	3.096	193.1
144	355.0	863.9	325.8	1189.7	3251	3.076	191.8
145	355.6	863.5	326.4	1189.9	3272	3.056	190.6
146	356.1	863.1	326.9	1190.0	3293	3.037	189.4
147	356.7	862.7	327.5	1190.2	3315	3.017	188.1
148	357.2	862.3	328.0	1190.3	3336	2.998	186.9
149	357.8	861.9	328.6	1190.5	3357	2.979	185.7
150	358.3	861.5	329.2	1190.7	3378	2.960	184.6
151	359.0	861.1	329.8	1190.9	3400	2.941	183.4
152	359.5	860.7	330.3	1191.0	3421	2.923	182.2
153	360.0	860.4	330.8	1191.2	3442	2.905	181.2
154	360.5	860.0	331.4	1191.4	3463	2.887	180.0
155	361.1	859.6	331.9	1191.6	3484	2.870	179.0

TABLE 271 SATURATED STEAM (*continued*)

Absolute Pressure per Square Inch.	Temperatures.	Total Latent Heat of Steam from Water supplied at 32° F.	Water heat of Steam (to raise temperature of Water from 32° F.	Total Heat of One Pound of Steam from Water supplied at 32° F.	Density, or Weight of One Cubic Foot of Steam.	Volume of One Pound of Steam.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water.
1	2	3	4	5	6	7	8
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
156	361.6	849.2	332.5	1181.7	3595	2.853	177.9
157	362.1	858.9	332.9	1191.8	3527	2.896	176.8
158	362.6	858.5	333.5	1192.0	3548	2.818	175.7
159	363.1	858.1	334.0	1192.1	3569	2.802	174.7
160	363.6	857.8	334.5	1192.3	3590	2.785	173.7
165	366.0	856.2	336.7	1192.9	3696	2.706	168.7
170	368.2	854.5	339.2	1193.7	3801	2.631	164.1
175	370.8	852.9	341.6	1194.4	3905	2.559	159.7
180	372.9	851.3	343.8	1195.1	4011	2.493	155.5
185	375.3	849.6	346.2	1195.8	4115	2.430	151.5
190	377.5	848.0	348.5	1196.5	4220	2.370	147.8
195	379.7	846.5	350.7	1197.2	4324	2.313	144.2
200	381.7	845.0	352.8	1197.8	4419	2.263	141.1

STEAM ENGINES AND BOILERS.

Steam Engines.

The work of steam in the cylinder is in two parts.—the work during admission, and the work done during expansion after the steam is cut off.

The absolute work done during admission is,

$$aPl, \text{ or } aP(l' - c) \quad (1)$$

The absolute work done during expansion to the end of the stroke, is

$$aPl + \text{hyp. log. } R \quad (2)$$

Here, for purposes of calculation, the hyperbolic law of expansion is assumed; according to which the pressure varies inversely as the volume.

The sum for these two quantities gives the total absolute work for one stroke, or, by reduction,

$$w = aP[l' (1 + \text{hyp. log. } R) - c]$$

In this expression an absolute vacuum for the whole of the return stroke is supposed. But there is the work of back pressure of exhaust and compression to be deducted, the is:—

$$w' = a p' L \quad (6)$$

and the net work is $w - w'$, or

$$W = a [P (L' (1 + \text{hyp. log } R)) - p' L] \quad (7)$$

In this expression it is assumed that the whole of the steam is expanded to the end of the steam-stroke; or that there is no material loss by commencing the exhaustion of steam before the end of the stroke.

L = length of stroke, in feet.

L' = period of admission, or length cut off, excluding clearance, in feet.

c = total clearance for one end of the cylinder in parts of foot of the stroke.

L' = length of stroke plus clearance.

R = period of admission plus clearance.

R = actual ratio of expansion.

a = area of piston, in square inches.

P = absolute pressure during admission, supposed uniform in pounds per square inch of piston area.

p = average absolute positive pressure for the whole stroke in pounds per square inch.

p' = average absolute back pressure for whole stroke, in pounds per square inch.

w = whole absolute work for one stroke, per square inch, in foot pounds.

w' = absolute work of back pressure for one stroke, per square inch in foot pounds.

W = net work for one stroke per square inch in foot pounds.

n = number of double strokes or revolutions of the engine.

The net horse-power of a double-acting steam-engine, for which the work has been calculated as above, is expressed by the following quantity:—

$$\frac{W \times n \times 2 \times a}{33000} ; \text{ or } \frac{W n a}{16500} \quad (8)$$

To calculate the net horse-power from the ordinary indicator diagram, in which all deviations from the above ideal performances are aggregated, find the effective mean pressure $p - p'$, per square inch on the piston for the whole of the stroke.

Thus —

$$\text{I.H.P.} = \frac{(p - p') \times a \times 2L \times n}{33000} ; \text{ or} \quad (9)$$

$$\text{I.H.P.} = \frac{(p - p') a L n}{16500} \quad (10)$$

In practice, the value ($p - p'$) may be taken by direct measurements of the net area of pressure circumscribed by the diagram.

TABLE 272.—WORK OF ONE POUND OF STEAM IN THE CYLINDER

Point of Admission, or Cut-off		Total Absolute Work done.	Steam per Total Absolute Horse Power per Hour.	Average Total Press. sure, that for 100 per cent. Admission being 1000.	Net Capacity of Cylinder per lb. of 100 lbs. steam (absolute pressure) ad- mitted in one Stroke.
Per cent.	Fraction	Ft. Lbs.	Pounds.		Cubic Feet
90	or $\frac{9}{10}$	63,870	31.0	906	4.45
80	" $\frac{4}{5}$	70,246	28.2	980	4.98
75	" $\frac{3}{4}$	78,543	26.9	969	5.26
70	" $\frac{2}{3}$	77,212	25.6	953	5.63
66.6	" $\frac{2}{3}$	79,555	24.9	942	5.87
62.5	" $\frac{5}{8}$	83,055	23.8	925	6.23
60	" $\frac{1}{2}$	85,125	23.3	913	6.47
55	" $\frac{1}{2}$	89,357	22.2	888	6.98
50	" $\frac{1}{2}$	94,200	21.0	860	7.61
45	" $\frac{1}{2}$	98,849	20.0	827	8.30
40	" $\frac{2}{5}$	104,406	19.0	787	9.23
37.5	" $\frac{3}{8}$	107,050	18.5	766	9.71
33.3	" $\frac{1}{3}$	112,220	17.7	726	10.72
30	" $\frac{1}{3}$	116,885	16.9	692	11.74
25	" $\frac{1}{4}$	124,066	16.0	637	13.56
20	" $\frac{1}{5}$	132,770	14.9	567	16.19
16.7	" $\frac{1}{6}$	138,130	14.34	526	18.21
14.3	" $\frac{1}{7}$	142,180	13.92	488	20.23
12.5	" $\frac{2}{16}$	146,325	13.53	457	22.25
11.1	" $\frac{1}{9}$	148,940	13.29	432	23.87
10.0	" $\frac{1}{10}$	151,370	13.08	413	25.49
9.0	" $\frac{1}{11}$	152,595	12.98	398	26.71
8.3	" $\frac{1}{12}$	153,260	12.75	381	28.38
7.7	" $\frac{1}{13}$	156,960	12.61	369	29.54
7.1	" $\frac{1}{14}$	157,975	12.53	357	30.76
6.7	" $\frac{1}{15}$	158,414	12.25	348	31.57
6.4	" $\frac{1}{16}$	159,433	11.83	342	32.38

The absolute work done by one pound of steam of absolute pressure varying from 67 lbs. to 160 lbs., worked expansively, with the consumption per absolute horse-power are given approximately in the Table 272. No correction need be made

for clearance space, nor for the resistance of compression; the period of compression can be so adjusted that the loss by resistance is compensated by the gain of exhaust steam shut into the cylinder. But, for the back pressure of exhaust, whether from the condenser or from the atmosphere, suitable allowance is to be made. The pressure during admission in the cylinder is supposed to be uniform; and the steam is supposed to be expanded to the end of the stroke.

The values in the last column—net capacity per pound of steam of 100 lbs. absolute pressure per square inch—are to be modified for steam of other pressures in the ratio of the volume of 100 lbs. steam to that of steam of other pressure. The multipliers are here given for absolute pressures of from 65 lbs. to 160 lbs. —

Pressures.	Multipliers	Pressures	Multipliers	Pressures	Multipliers
lbs.		lbs.		lbs.	
65	1.50	90	1.11	130	.781
70	1.40	95	1.05	140	.730
75	1.31	100	1.00	150	.683
80	1.24	110	.917	160	.644
85	1.17	120	.843		

The effective mean pressure in ordinary non-condensing cylinders, with ordinary slide valve and excentric motion, and a like motion, working at average speeds, is given approximately by the equation:—

$$p = 13.5 \sqrt{a} - 28 \quad . \quad . \quad . \quad (6)$$

p = effective mean pressure, in per cent. of the maximum pressure of admission.

a = period of admission, in per cent. of the length of stroke.

For a speed of 560 feet of piston per minute, the formula is applicable without material error. For lower speeds, the values of the effective mean pressures are slightly too small; and for higher speeds slightly too great. The rule applies without material error to periods of admission of from 10 per cent. to 75 per cent., and to maximum pressures in the cylinder of from 60 lbs. to 160 lbs. or even 150 lbs. per square inch.

The Table 273 has been calculated by means of the above formula:—

TABLE 273 — EFFECTIVE MEAN PRESSURES IN NON-CONDENSING CYLINDER, FOR VARIOUS PERIODS OF ADMISSION, FROM PRACTICE.

(“Railway Machinery.”)

Period of Admission, in per cent of the Stroke	Effective Mean Pressure, in per cent of Maximum Pressure	Period of Admission, in parts of the Stroke	Effective Mean Pressure, in parts of Maximum Pressure
Per Cent	Per Cent	Fraction	Fraction
10	15	1-10th	1-7th Early
12.5	20	1-8th	1-5th
15	24	..	..
17.5	28	1-6th	1-4th
20	32	1-5th	1-3rd
25	40	1-4th	1-2.5th part
30	46	..	...
35	52	1-3rd	1-2nd
40	57	...	...
45	62	..	...
50	67	1-2nd	2-3rds
55	72	...	..
60	77	..	..
65	81	2-3rds	4-5ths
70	85	..	...
75	89	3-4ths	9-10ths

When gaseous steam is expanded in the cylinder, it follows approximately the adiabatic law, the essential condition of which is that the cylinder should be non-conductive. The formula for gaseous steam is as follows:—

$$P' = P \times \left(\frac{r'}{r} \right)^{1.333} \quad (10)$$

P = absolute pressure, say in pounds per square inch, for the given volume V

P' = absolute pressure, in pounds per square inch, for any other volume V'

r = initial volume, say in cubic feet

r' = volume by expansion, in cubic feet.

Any number of pressures with expansion may be calculated by the formula, and thus the expansion-curve may be determined; for comparison with expansive curves of ordinary steam, using saturated steam.

Valve Motions.

In slide-valves for the distribution of the steam in the cylinder—taking an ordinary valve for a three-port cylinder—the lap, or cover, is the length by which the valve overlaps the steam port at each end; the lead is the length of opening of each steam port for steam at the beginning of the stroke; and the linear advance of the valve is the sum of the lap and the lead. Inside

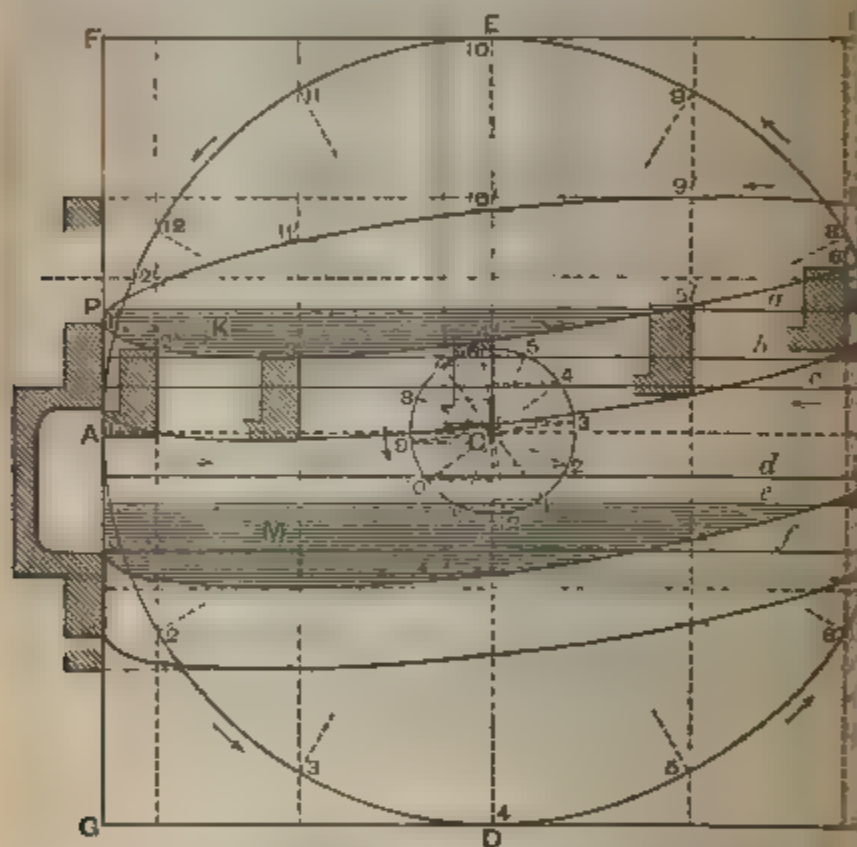


FIG. 70. Valve-diagram.

occasionally applied to slide-valves; it is the width by which the inner edge of the valve, when the valve is in its middle position, overlaps the inner edge of the steam port. The angular advance is the angle formed by the eccentric with the vertical at its half-stroke, when the piston is at the commencement of its stroke.

The movements of sliding valves worked by an eccentric are equivalent to an equivalent motion—as that of ordinary expansion.

may be established by means of diagrams, exemplified in fig. 79.

To construct this diagram, draw AB equal to the length of the piston, and bisect it at C . On C as a centre, with CB as a radius, describe a circle representing the path of the piston, and describe also the circle DE for that of the excentric. Through C draw the perpendicular, and construct a square on the large circle. Let the rectangle be taken to represent the ordinary three-ported valve-cylinder, and set off the ports and bars above and below the centre-line AB , and through the points draw the ordinates a, b, c, d, e, f . The movement of the excentric is taken to be in the direction AB , and is directly determined by the position of the centre of the excentric; and that of the piston is taken as in the direction of DE . The position of the valve is represented by the dot lines in the diagram parallel to AB , which represent its total travel, and they overlap the outer edges a and f of the steam cylinder a length representing the lap. For the first position of the valve—at the beginning of the stroke—it is placed at a distance equal to the linear advance, or the lap plus the lead, from the middle position, as measured on the perpendicular through the corresponding first position of the excentric, on the vertical centre-line ED . Divide both circles into 12 parts, numbered in succession from point No. 1 to 12, and draw radial lines through the points of division to represent the successive simultaneous positions of the piston and the excentric. The transverse lines drawn through the points of division on the larger circle parallel to DE , represent the corresponding positions of the piston during the inward and outward strokes, and the perpendiculars drawn to DE from the points of division of the smaller circle, represent the simultaneous longitudinal movements of the excentric, or the distances of the valve-edges above or below the middle positions. These are set off on the ordinates of DE , and they range in elliptic curves as inscribed in the diagram, representing the whole movements of the valve in a double stroke of the piston, or one revolution of the

A valve-diagram fig. 80, affords a simple means of determining the points of the distribution of steam. Draw two lines AB and CD , at right angles, intersecting at O ; and with radius AO , equal to half the travel of the valve, describe the circle AB , taken to represent the path of the valve. Set off the diameter aOa' , at the angle aOa' , equal to the angular advance of the excentric; and on the line Ca' describe the circle CD , and Ca' will be the

centre O , with the radius $O b$, equal to the outside lap of the valve, describe a circle cutting the circle $a O$ at b and b' ; and from these points of intersection, draw the radii $O f$ and $O g$. Draw the diameter $d O e$ at right angles to the diameter $a O c$. Taking $A B$ for the stroke of the piston, the point f , is the position of the crank-pin when the valve opens for lead at

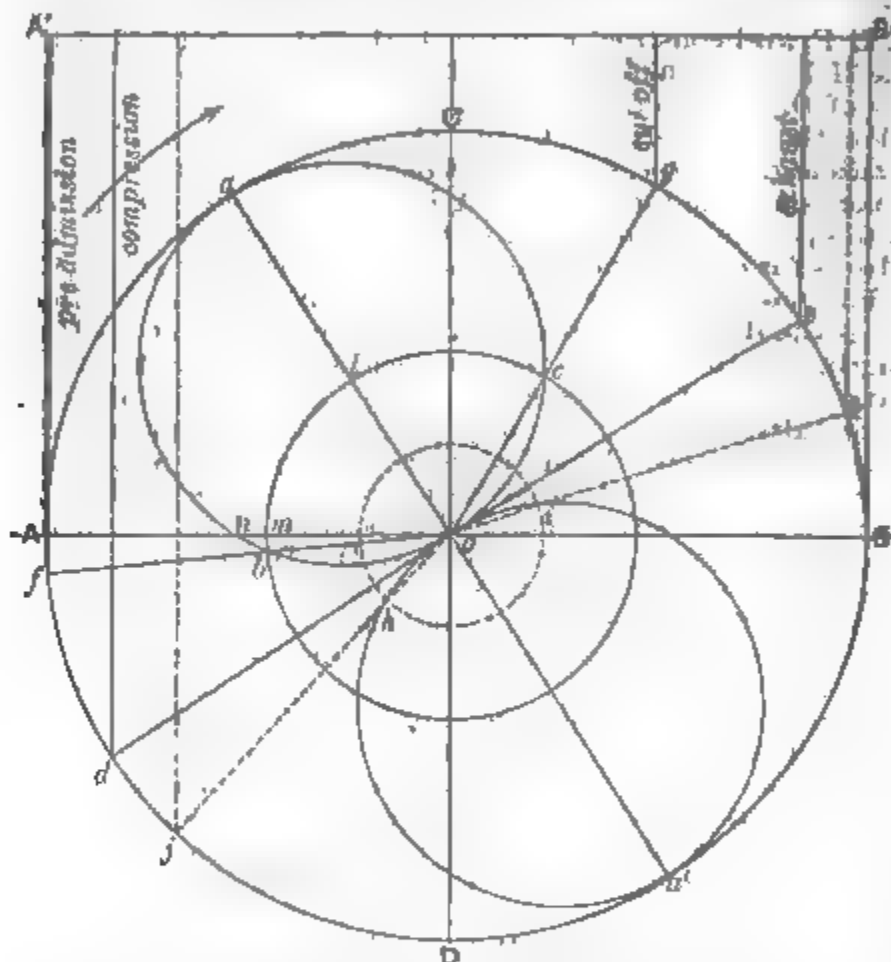


FIG. 80. Zeuner's Valve-diagram.

A , the beginning of the stroke, g is the position when the steam is cut off; e is the position when the valve is opened for exhaust; and d is the position when the exhaust side of the valve is closed for compression. In this case, there is no inside lap.

For a case of inside lap on the valve, describe the circle $h i$, with a radius equal to the inside lap, cutting the circle $O a'$ at h and i , and through these points draw the radii $O j$, and $O k$. The point h , in the outer circle, is the position of the crank-

the exhaust is opened, and the point *j* is the position of the valve when the exhaust is closed for compression.

Draw a line *A'B'* parallel to the base line *A B*, and draw perpendiculars from the several points of the distribution, in

274. CORRECTIONS FOR THE POSITION OF THE VALVE, DUE TO THE OBLIQUITY OF THE CONNECTING-ROD.

Distance of Piston from
the Center of Stroke, as
determined by the progress
of the Crank, in
Percentage of the Stroke.

Corrections for Connecting Rods of
Several Lengths related to the Length
of the Crank, in percentages of the
Whole Stroke

Dist.	Per Cent.	Four Lengths of Crank.	Six Lengths of Crank.	Eight Lengths of Crank.
		Per Cent	Per Cent	Per Cent
100		0	0	0
98		0½	0½	0½
96		1	0½	0½
94		1½	1	0½
92		2	1½	1
90		2½	1½	1
88		2½	1½	1½
86		3	2	1½
84		3½	2½	1½
82		4	2½	2
80		4	2½	2
78		4½	3	2½
76		4½	3	2½
74		5	3½	2½
72		5	3½	2½
70		5½	3½	2½
68		5½	3½	2½
66		5½	3½	3
64		6	4	3
62		6	4	3
60		6	4	3
58		6½	4	3
56		6½	4½	3
54		6½	4½	3
52		6½	4½	3½
50		6½	4½	3½

A B. The intersections of these ordinates with the
line *A B* give the points of the distribution for the double

ing-rod, inasmuch that during the front stroke—that is to stroke made towards the crank—the piston is in advance of its normal position, as represented by the progress longitudinally of the crank-pin; and during the back stroke, it is behind its normal position. The corrections in per cent. of the stroke are given in Table 274, for three different lengths of connecting rod, in proportion to the length of the crank. They are additive for front strokes, and subtractive for back strokes. They have been calculated by means of the formula (11) (*Railway Machinery*)

$$x = ar \sqrt{(a^2 - 1)r^2 + b^2} \quad (11)$$

a = length of connecting-rod in parts of that of the crank;
 b = distance of piston from the middle of the stroke as represented by the progress longitudinally of the crank.

r = length of crank.

x = the correction.

Rules for Valves.

1. *For the angular advance of the eccentric.* Divide the linear advance by the half-travel; the quotient is the sine of the angle of advance; and the angle, which is acute, may be found in a table of sines.

2. *For the period of admission or point of cut-off.* Divide the lap by the half-travel of the valve; the quotient is the sine of the angle of the eccentric at the instant of cut-off; if the angle is obtuse and is found in a table of sines. From this angle subtract the angle of advance as found by Rule 1; the difference is the angle of the crank. If this angle is obtuse, add 1 to its cosine; if acute, subtract it from 1. The product of the sum or the difference by 50, is the percentage of admission.

3. *For the period of compression.* Subtract the cosine of the angle of advance from 1, and multiply by 50, to find the percentage of the period of compression.

These rules may be employed for link-motions, and generally for all valve-motions based on the motion of eccentrics.

By means of the first and second rules, the following table 276, has been calculated with a constant lead, $\frac{1}{8}$ inch.

When it is desired that the lap, lead, and travel of the slide valve should bear constant ratios to each other, the following general rule is useful.—

4. Given the travel, to find the lap and lead suitable for admission of about 75 per cent. of the stroke.

1st for lap, multiply the travel by 22, and divide by 10.

2nd for lead, multiply the travel by 7, and divide by 10.

By this rule, the Table 275, has been calculated.

TABLE 275.—LAP AND LEAD OF SLIDE-VALVES, PROPORTIONED FOR VARIOUS TRAVELS, FOR AN ADMISSION OF ABOUT 75 PER CENT OF THE STROKE.

Travel of Valve	Lap.	Lead	Travel of Valve.	Lap.	Lead
Inches	Inches.	Inch.	Inches	Inches.	Inch.
1½	33 or $\frac{5}{16}$ $\frac{1}{8}$	10 or $\frac{3}{32}$	3½	71 or $\frac{11}{16}$ $\frac{3}{8}$	22 or $\frac{3}{16}$ $\frac{1}{2}$
1¾	36 " $\frac{3}{8}$ $\frac{1}{8}$	11 " $\frac{1}{16}$ $\frac{3}{64}$	3¾	77 " $\frac{13}{16}$ $\frac{1}{8}$	24 " $\frac{3}{16}$ $\frac{3}{8}$
1⅝	38 " $\frac{7}{16}$	12 " $\frac{1}{8}$	3¾	82 " $\frac{13}{16}$	26 " $\frac{1}{2}$
1⅞	41 " $\frac{1}{2}$ $\frac{1}{8}$	13 " $\frac{1}{4}$	4	88 " $\frac{13}{16}$	28 " $\frac{1}{2}$ $\frac{1}{32}$
2	44 " $\frac{1}{2}$	14 " $\frac{1}{4}$ $\frac{1}{8}$	4¼	93 " $\frac{13}{16}$	30 " $\frac{1}{2}$ $\frac{3}{64}$
2¼	47 " $\frac{1}{2}$ $\frac{1}{32}$	15 " $\frac{1}{4}$ $\frac{3}{32}$	4½	99 " 1 00	31 " $\frac{1}{2}$
2½	50 " $\frac{3}{4}$	16 " $\frac{1}{4}$ $\frac{1}{8}$ $\frac{3}{32}$	4¾	1 04 " $1 \frac{1}{64}$	33 " $\frac{1}{2}$ $\frac{1}{64}$ $\frac{1}{84}$
2¾	52 " $\frac{3}{4}$ $\frac{1}{64}$	17 " $\frac{1}{4}$ $\frac{1}{8}$ $\frac{3}{64}$	5	1 10 " $1 \frac{1}{8}$ $\frac{1}{32}$	35 " $\frac{1}{2}$ $\frac{1}{32}$
2⅞	55 " $\frac{3}{4}$ $\frac{1}{64}$	17 " $\frac{1}{4}$ $\frac{3}{64}$	5¼	1 15 " $1 \frac{1}{8}$ $\frac{1}{32}$	37 " $\frac{1}{2}$
2⅞	58 " $\frac{3}{4}$ $\frac{1}{64}$	18 " $\frac{1}{4}$ $\frac{1}{16}$	5½	1 21 " $1 \frac{1}{8}$ $\frac{1}{16}$ $\frac{1}{64}$	38 " $\frac{1}{2}$
2¾	60 " $\frac{15}{16}$ $\frac{1}{32}$	19 " $\frac{1}{4}$ $\frac{1}{16}$	5¾	1 26 " $1 \frac{1}{8}$	40 " $\frac{1}{2}$ $\frac{1}{32}$
2¾	63 " $\frac{15}{16}$	20 " $\frac{1}{4}$ $\frac{1}{16}$ $\frac{1}{64}$	6	1 32 " $1 \frac{1}{8}$	42 " $\frac{1}{2}$ $\frac{1}{64}$ $\frac{1}{32}$
3	66 " $\frac{15}{16}$ $\frac{1}{32}$	21 " $\frac{1}{4}$ $\frac{1}{16}$ $\frac{1}{64}$	6¼	1 50 " $1 \frac{1}{4}$	47 " $\frac{1}{2}$ $\frac{1}{16}$ $\frac{1}{32}$

In the Table 276, following, is shown the relative distribution for a slide-valve of the proportions assumed in rule 4, above; with admissions varied from 73½ per cent. (say 75) to 12 per cent., for the corresponding travels given in the last two columns.

TABLE 276.—DISTRIBUTION FOR VARIOUS TRAVELS OF A VALVE OF STANDARD PROPORTIONS.

Steam Out-off	Steam Exhausted.	Point of Compression.	Point of Admission.	Travel of the Valve. Lap 1 Inch. Lead $\frac{1}{16}$ Inch.	
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Inches.	Per Cent. of Maximum Travel.
75	91	9	62	4½	100
60	86	14	1 10	3¾	83
50	80	20	1 20	3¾	75
40	75	25	2 50	3½	67
30	68	32	4 35	2½	62
20	57	43	7 60	2¼	60
12	50	50	12 25	2¼	58.3

TABLE 277 PERIODS OF ADMISSION FOR VARIOUS TRAVELS AND LAPS OF THE SLIDE-VALVE

Lead $\frac{5}{16}$ inch.

Travel	Lap in inches.							
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$
Periods of Admission in Percentages of Stroke								
Inches								
$\frac{1}{8}$	19					7		
$\frac{1}{4}$	39							
$\frac{3}{8}$	47	17						
$\frac{1}{2}$	55	34						
$\frac{5}{8}$	61	42	14					
$\frac{3}{4}$	65	50	30					
$\frac{7}{8}$	68	55	38	18				
1	74	59	46	27				
$1\frac{1}{8}$	74	63	49	36	12			
$1\frac{1}{4}$	76	67	56	43	26			
$1\frac{1}{2}$	78	70	59	47	32	11		
$1\frac{3}{4}$	80	73	62	50	38	23		
2	81	74	65	55	44	30	10	
$2\frac{1}{8}$	83	76	68	59	48	34	22	
$2\frac{1}{4}$	84	78	71	62	51	40	29	9
$2\frac{1}{2}$	85	80	73	64	53	45	34	20
$2\frac{3}{4}$	86	81	75	66	57	49	38	26
3	87	82	76	69	60	52	42	32
$3\frac{1}{8}$	87	83	78	70	63	55	46	36
$3\frac{1}{4}$	88	84	79	72	66	58	49	40
$3\frac{1}{2}$	89	86	81	76	70	63	56	47
$3\frac{3}{4}$	90	87	83	79	73	67	61	54
4	92	89	85	81	76	70	65	58
$4\frac{1}{8}$	93	90	87	83	78	73	67	62
$4\frac{1}{4}$	94	92	89	86	82	78	73	68
$4\frac{1}{2}$	95	93	91	88	85	82	78	74

TABLE 278.—PERIODS OF ADMISSION OR POINTS OF CUT-OFF, FOR GIVEN TRAVELS AND LAPS OF SLIDE-VALVES.

Travel of Valve	Lead of Valve	Periods of Admission, or Points of Cut-off, for the following Laps of valve, in Inches, in Percentages of Stroke.									
		2	1½	1½	1¼	1	¾	¾	¾	¾	¾
Inches.	Inch.										
12	½	88	90	93	95	96	97	98	98	99	99
10	½	82	87	89	92	95	96	97	98	98	99
8	½	72	78	84	88	92	94	95	96	98	98
6	½	50	62	71	79	86	89	91	94	96	97
5½	½	43	56	68	77	85	88	91	94	96	97
5	½	32	47	61	72	82	86	89	92	95	97
4½	½	14	35	51	66	78	83	87	90	94	96
4	½	..	17	39	57	72	78	83	88	92	95
3½	½	..	..	20	44	63	71	79	84	90	94
3	½	..	..	..	23	50	61	71	79	86	91
2½	½	..	..	..	..	27	43	57	70	80	88
2	½	..	..	..	..	..	33	52	70	81	81

Woolf Engine:—Continuous Expansion in two Cylinders.

The total work for one stroke of the two pistons, may be calculated by the formula (5), page 504, for the work of a single cylinder.

Receiver Engine: Successive Expansions in two Cylinders.

The total work for one stroke of the two pistons, may be calculated by the formula—

$$w = a P \left[P' (1 \times \text{hyp. log. } R'') - c \left(1 \times \frac{r-1}{R'} \right) \right] \quad (12)$$

In the construction of the foregoing formula, it is assumed that the line of pressure during admission of steam is straight and parallel to the datum-line, that the expansion curves are hyperbolic to the end of the strokes, that the exhaust is open to the end of the return stroke of the second piston; and that there is no back pressure on it.

The work of back pressure is most directly measured from the indicator diagram, in which the other modifications of performance due to compression, and wiredrawing may also be measured.

RULE.—To find the indicator horse-power of a single cylinder steam engine, from the indicator diagram. Multiply the area of the piston in square inches by the effective mean pressure on the piston in pounds per square inch, and by twice the length of the stroke, and by the number of revolutions per minute, and divide the product by 33,000. The quotient is the indicator horse-power.

For compound and multiple-expansion engines, the indicator power in each cylinder is calculated separately; and the sum of the powers thus obtained is the total indicator horse-power. When strokes of the pistons are equal, and if the horse-power of the cylinders are not required separately, it will suffice to multiply the area of each piston by the effective mean pressure, and to complete the calculation with the sum of the products.

The best performance of steam engines under various conditions, may be accepted approximately to be as follows. —

Single Cylinders, not steam-jacketed, non-condensing. — Steam cut off at one-third of the stroke, and consumed at the rate of 26 pounds per indicator horse-power per hour; the effective pressure during admission being 60 lbs. per square inch.

Single Cylinders, using superheated steam, non-condensing. — With 80 lbs. effective pressure of steam during admission, cutting off at one-fifth, 18½ pounds of steam consumed per indicator horse-power per hour. For a lower effective mean pressure of 54 lbs. per square inch, cutting off at about 30 per cent. with 130 degrees of superheat, about 30½ pounds of steam are consumed per indicator horse-power per hour.

Single Cylinders, steam-jacketed, non-condensing. — With 75 lbs. effective pressure during admission, cutting off at one-fifth, 25 pounds of steam are consumed per indicator horse-power per hour.

Single Cylinders, with superheated steam, condensing. — With 65 lbs. effective pressure during admission, and 130 degrees of superheat, cutting off at 22½ per cent. of the stroke 15½ pounds of steam are consumed per indicator horse-power per hour.

Single Cylinders, not steam-jacketed, condensing. — The economical results are affected by the length of the stroke relatively to the diameter. In strokes considerably longer than the diameters, an admission of from 15 per cent. to 20 per cent. is most efficient for economy. With initial steam of 80 lbs. total pressure per square inch, approximately 20 pounds of steam are consumed per indicator horse-power per hour.

For short-stroke cylinders—having strokes considerably shorter than two diameters—with initial steam of 73 lbs. total pressure, approximately 23 pounds of steam are consumed per horse-power.

Single Cylinders, steam-jacketed, condensing.—The period of admission most favourable for economy, is from 15 per cent. to 25 per cent. of the stroke. For thoroughly steam-jacketed cylinders, of long strokes, the longer periods of admission are preferable; and for those of short strokes, the shorter periods. For cylinders jacketed only at the sides of barrel, the longer ranges are preferable. With thoroughly steam-jacketed cylinders of long stroke, and steam of 80 lbs. total initial pressure, about $18\frac{1}{2}$ pounds of steam are consumed per indicator horse-power per hour; and for cylinders of short stroke, 21 pounds.

Woolf Compound Steam Engines.

Proportionally long strokes, compared with proportionally short strokes, are conducive to economy. With a stroke of five diameters, and a total initial pressure of 100 lbs. per square inch, and worked with 12 actual expansions, the work is done for about 14 pounds of steam per indicator horse-power per hour. With a stroke equal to twice the diameter, $17\frac{1}{2}$ pounds are consumed.

Receiver Compound Steam Engines.

With a stroke equal to from two to three diameters of the first cylinder, for a total initial pressure of from 80 lbs. to 90 lbs. per square inch, cutting off at one fifth, and ten actual expansions, with thorough jacketing and intermediate heating of steam, the work may be done with a consumption of 15 pounds of steam per indicator horse-power per hour. With shorter strokes—from $1\frac{1}{2}$ to $1\frac{3}{4}$ diameters— $18\frac{1}{2}$ pounds are consumed. Without steam jacketing, the consumption of steam is from 2 pounds to 3 pounds more.

Capacity-ratio of Multiple Expansion Cylinders.

For speed of piston of from 750 feet to 1000 feet per minute, the capacity-ratios of triple-expansion steam engines, given in the following Table, are recommended. They are based upon a wide range of practice. The terminal absolute pressure of steam in the third cylinder, is supposed to be about 10 lbs. per square inch.

**TABLE 279.—TRIPLE-EXPANSION STEAM ENGINES.
CAPACITY-RATIOS OF CYLINDERS RECOMMENDED.**

(Jay M. Whitham.)

Gauge Pressure per Square Inch in the Boiler.	Capacity-Ratios of Cylinders.		
	1st (Small).	2nd (Intermediate).	3rd (Large).
Pounds.	Ratio.	Ratio.	Ratio.
130	1	2.25	5.00
140	1	2.40	5.85
150	1	2.55	6.90
160	1	2.70	7.25
170			
and upwards	Quadruple expansion to be adopted.		

For quadruple expansion, with steam of, say, 180 lbs. per square inch, capacity-ratios of four cylinders, taken as 1, 2, 4, 8, are very suitable.

Efficiency and Frictional Resistance of Steam Engines.

The frictional resistance of steam engines varies inversely as their leading dimensions. A direct-action engine having a 4-inch cylinder, yielded at the main shaft only 43 per cent. of the indicator power, with a frictional resistance of 57 per cent.

Eight horse-power portable engines, having 9-inch cylinders, yield from 78 per cent. to 87 per cent., with from 13 per cent. to 22 per cent. of resistance.

Corliss engines having 18-inch and 24-inch cylinders, yield about 90 per cent. of the indicator power at the main shaft; with about 10 per cent. of resistance.

Compound engines having first cylinders of from 12 inches to 21 inches in diameter, with or without a beam, yield from 80 per cent. to 89 per cent. of the indicator power.

Rotative pumping steam engines yield from 80 per cent. to 86 per cent. of duty; Worthington's large pumping engines for waterworks, yield 91 per cent. So also do Cornish pumping engines.

From the results of experiments made by Dr. Thurston, on the distribution of friction in direct-acting non-condensing steam engines having balanced valves, it appears that from 40 per cent. to 47 per cent. of the resistance arises at the main bearings; about 33 per cent. at the piston and its rod, 7 per cent. at the crank-pin, $5\frac{1}{2}$ per cent. at the crosshead and

pin when the exhaust is opened, and the point *y* is the position when it is closed for compression.

Draw a parallel *A' B'* to the base-line *A B*, and draw ordinates to it from the several points of the distribution.

TABLE 274.—CORRECTIONS FOR THE POSITION OF THE PISTON, DUE TO THE OBLIQUITY OF THE CONNECTING ROD

Distance of Piston from Commencement of Stroke, as represented by the progress longitudinally of the Crank, in percentage of the Stroke.		Corrections for Connecting-Rods of Several Lengths related to the Length of the Crank in percentages of the Whole Stroke		
Per Cent.	Per Cent.	Four Lengths of Crank.	Six Lengths of Crank.	Eight Lengths of Crank.
0	100	0	0	0
2	98	$0\frac{1}{2}$	$0\frac{1}{4}$	$0\frac{1}{4}$
4	96	1	$0\frac{1}{2}$	$0\frac{1}{2}$
6	94	$1\frac{1}{2}$	1	$0\frac{3}{4}$
8	92	2	$1\frac{1}{2}$	1
10	90	$2\frac{1}{2}$	$1\frac{3}{4}$	1
12	88	$2\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{1}{4}$
14	86	3	2	$1\frac{1}{2}$
16	84	$3\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{3}{4}$
18	82	$3\frac{3}{4}$	$2\frac{1}{2}$	2
20	80	4	$2\frac{3}{4}$	2
22	78	$4\frac{1}{2}$	3	$2\frac{1}{4}$
24	76	$4\frac{1}{2}$	3	$2\frac{1}{4}$
26	74	5	$3\frac{1}{4}$	$2\frac{1}{2}$
28	72	5	$3\frac{1}{4}$	$2\frac{1}{2}$
30	70	$5\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{3}{4}$
32	68	$5\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{3}{4}$
34	66	$5\frac{3}{4}$	$3\frac{3}{4}$	3
36	64	6	4	3
38	62	6	4	3
40	60	6	4	3
42	58	$6\frac{1}{4}$	4	3
44	56	$6\frac{1}{4}$	$4\frac{1}{4}$	3
46	54	$6\frac{1}{4}$	$4\frac{1}{4}$	3
48	52	$6\frac{1}{2}$	$4\frac{1}{4}$	$3\frac{1}{4}$
50	50	$6\frac{1}{2}$	$4\frac{1}{4}$	$3\frac{1}{4}$

the circle *A B*. The intersections of these ordinates with the parallel *A' B'* give the points of the distribution for the double stroke of the piston.

The distribution is affected by the obliquity of the connecting

centre O , with the radius $O b$, equal to the outside lap of the valve, describe a circle cutting the circle $a O$ at b and c ; from these points of intersection, draw the radii $O f$ and $O g$. Draw the diameter $d O e$ at right angles to the diameter $a O c$. Taking $A B$ for the stroke of the piston, the point f , is the position of the crank-pin when the valve opens for lead.

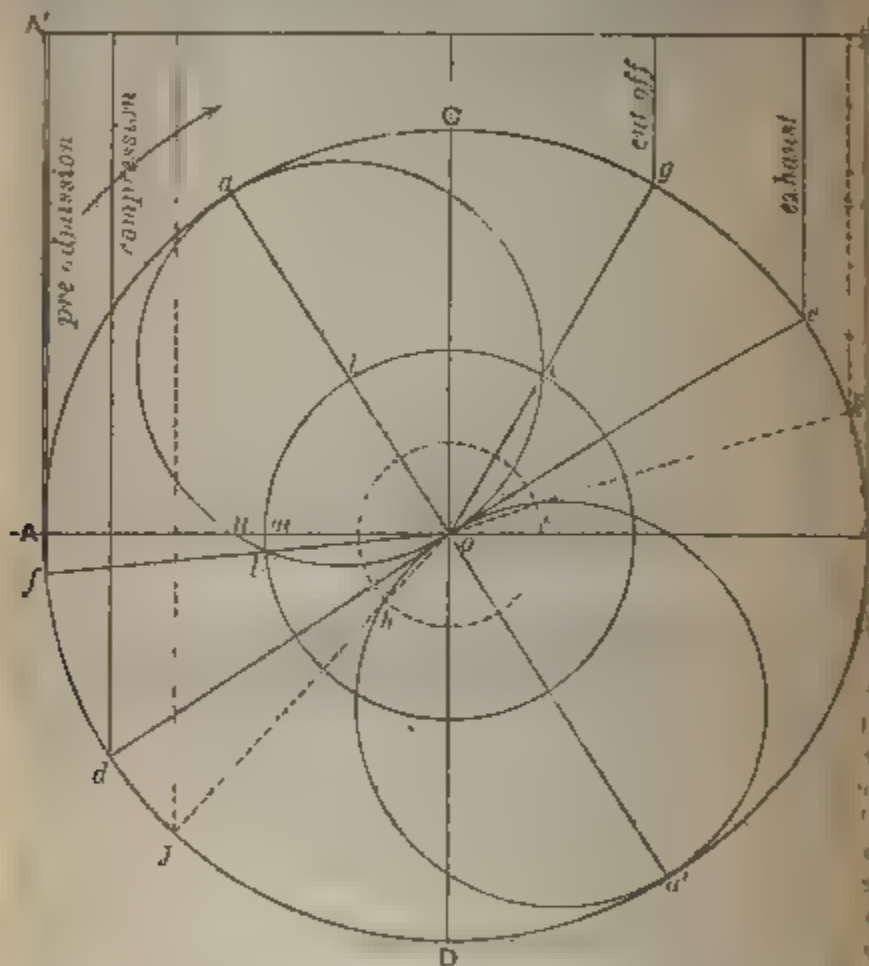


FIG. 80. Zeuner's Valve Diagram.

A , the beginning of the stroke, g is the position when the steam is cut off, e is the position when the valve is opened for exhaust; and d is the position when the exhaust side of the valve is closed for compression. In this case, there is no side lap.

For a case of inside lap on the valve, describe the circle $a O$ with a radius equal to the inside lap, cutting the circle $O b$ at h and i , and through these points draw the radii $O j$, and $O k$. The point h , in the outer circle, is the position of the

The side of a square chimney equal in sectional area to a given round chimney, is equal to the product of the diameter by 886, and the equivalent fraction of the height for the side of a square chimney is one thirty fourth.

Conversely, the diameter of a round chimney equal in sectional area to a given square chimney, is equal to the product of the side of the square by 1.13.

In Table 280, are given the quantity of coals that may be consumed per hour, at the assumed rate of 15 pounds per square foot per hour, and the corresponding total area of fire-grate, for chimneys of various heights, and corresponding diameters one-thirtieth of the respective heights.

TABLE 280 — FACTORY CHIMNEYS.

Chimney		Coal Consumable per Hour	Grate Area.	Chimney.		Coal Consumable per Hour.	Grate Area.
Height	Diameter			Height.	Diameter		
Feet	Ft. Ins.	Pounds.	Sq. Ft.	Feet	Ft. Ins.	Pounds	Sq. Ft.
40	1 4	142	9.5	110	3 8	1777	118.4
50	1 8	248	16.5	120	4 0	2208	147.2
60	2 0	390	26.0	135	4 6	2964	197.6
70	2 4	574	38.3	150	5 0	3858	257.2
80	2 8	801	53.4	165	5 6	4896	326.4
90	3 0	1076	71.7	180	6 0	6086	405.1
100	3 4	1394	93.0	200	6 8	7920	526.0

TABLE 281. HORSE-POWER IN VARIOUS COUNTRIES IN FOOT-POUNDS PER SECOND.

("Steam.")

Country.	Kilogram meters per sec.	Baden. per sec.	Saxony per sec.	Würtem- burg per sec.
		Foot-lbs.	Foot-lbs.	Foot-lbs.
France and Baden	75	500	529.68	521.58
Saxony	75.045	500.30	530	523.89
Württemberg	75.240	501.36	531.12	525
Prussia.	75.325	502.17	531.97	525.85
Hanover	75.361	502.41	532.28	526.10
England	76.041	506.94	537.03	530.84
Austria	76.119	507.46	537.58	531.39

TABLE 261. HORSE-POWER IN VARIOUS COUNTRIES.

Country.	Prussian per sec.	Hanoverian per sec.	English per sec.	Austrian per sec.
	Foot-lbs.	Foot-lbs.	Foot-lbs.	Foot-lbs.
France and Baden	477.93	513.83	542.47	423.68
Saxony	478.23	513.84	542.80	423.93
Württemberg	479.23	514.92	543.95	424.83
Prussia	480	515.75	544.82	425.51
Hanover	480.23	516	545.08	425.72
England	484.56	520.65	550	429.56
Austria	485.06	521.19	550.57	430

TABLE 282. ECONOMY OF FUEL BY HEATING THE FEED-WATER.
(For Steam of 60 lbs. per square inch Working Pressure.)

Initial Temperature of Water.	Final Temperature of Feed-Water (Fahrenheit).						
	120°	140°	160°	180°	200°	250°	300°
° Fahr.	%	%	%	%	%	%	%
82	7.50	9.20	10.90	12.86	14.80	19.03	22.80
85	7.25	8.96	10.66	12.09	14.09	18.34	22.60
40	6.85	8.57	10.28	12.00	13.71	17.99	22.27
45	6.45	8.17	9.90	11.61	13.34	17.64	21.94
50	6.05	7.71	9.50	11.23	13.00	17.28	21.61
55	5.64	7.37	9.06	10.85	12.60	16.93	21.27
60	5.23	6.97	8.72	10.46	12.20	16.58	20.92
65	4.82	6.56	8.32	10.07	11.82	16.20	20.58
70	4.40	6.15	7.91	9.68	11.43	15.83	20.23
75	3.98	5.74	7.50	9.28	11.04	15.46	19.88
80	3.55	5.32	7.09	8.87	10.65	15.08	19.52
85	3.12	4.90	6.68	8.46	10.25	14.70	19.17
90	2.68	4.47	6.26	8.06	9.85	14.32	18.81
95	2.24	4.04	5.84	7.65	9.44	13.94	18.44
100	1.80	3.61	5.42	7.23	9.03	13.55	18.07
110	.90	2.73	4.55	3.38	8.20	12.76	17.28
120	0	1.84	3.67	5.52	7.36	11.95	16.49
130	...	.92	2.77	4.64	6.90	11.14	15.24
140	...	0	1.87	3.75	5.62	10.31	14.99
150	...	...	.94	2.83	4.72	9.46	14.18
160	...	...	0	1.91	3.82	8.59	13.37
170	...	...	...	.96	2.89	7.71	12.54
180	...	...	...	0	1.96	6.81	11.70
190	...	...	...	...	.90	5.90	10.82
200	...	...	...	...	0	4.85	9.93

TABLE 288.—RELATIVE ECONOMY OF FEED-APPARATUS
(Jacobus.)

Feed Water how Supplied.	Relative Consumption of Coal.	Relative Economy Effected
Direct-acting pump, feeding water at 60°, without a heater . . .	1.000	0.0
Injector feeding water at 150° without a heater . . .	.985	1.5 per cent.
Injector feeding through a heater in which the water is heated from 150° to 200 . . .	.938	6.2 ..
Direct-acting pump, feeding water through a heater, in which it is heated from 60° to 200° . . .	.879	12.1 ..
Geared pump, run from the engine, feeding water through a heater, in which it is heated from 60° to 200 . . .	.808	18.2 ..

TABLE 284.—WEIGHT OF SEDIMENT COLLECTED IN A
STEAM-BOILER, FROM HARD WATER, EVAPORATED AT
THE RATE OF 1000 GALLONS PER DAY.

Solid Matter per Gallon Evaporated.	Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated	Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated.	Solid Matter per Gallon Evaporated.	Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated	Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated.
Grams.	Lbs. Ozs.	Lbs. Ozs.	Grams.	Lbs. Ozs.	Lbs. Ozs.
1	0 2.8	0 13.7	15	2 2.3	12 13.7
2	0 4.6	1 11.4	20	2 13.7	17 2.3
3	0 6.9	2 9.1	25	3 9.1	21 6.9
4	0 9.1	3 6.9	30	4 4.6	25 11.4
5	0 11.4	4 4.6	35	5 0	30 0
6	0 13.7	5 2.3	40	5 11.4	34 4.6
7	1 0	6 0	45	6 6.9	38 9.1
8	1 2.3	6 13.7	50	7 2.3	42 13.7
9	1 4.6	7 11.4	55	7 13.7	47 2.3
10	1 6.9	8 9.1			

TABLE 285.—MULTIPLIERS FOR FINDING THE EQUIVALENT FOR GIVEN PRESSURES OF STEAM AND

Temperature of Feed Water.	Boiler Pressures in Pounds									
	0	5	10	15	20	25	30	35	40	45
* Fahr.										
32	1.187	1.192	1.195	1.199	1.201	1.204	1.206	1.209	1.211	1.212
35	1.184	1.189	1.192	1.196	1.198	1.201	1.203	1.206	1.208	1.209
40	1.179	1.184	1.187	1.191	1.193	1.196	1.198	1.201	1.203	1.204
45	1.173	1.178	1.181	1.185	1.187	1.190	1.192	1.195	1.197	1.198
50	1.168	1.173	1.177	1.180	1.182	1.185	1.187	1.190	1.192	1.193
55	1.163	1.168	1.171	1.175	1.177	1.180	1.182	1.185	1.187	1.188
60	1.158	1.163	1.166	1.170	1.172	1.175	1.177	1.180	1.182	1.183
65	1.153	1.158	1.161	1.165	1.167	1.170	1.172	1.175	1.177	1.178
70	1.148	1.153	1.156	1.160	1.162	1.165	1.167	1.170	1.172	1.173
75	1.143	1.148	1.151	1.155	1.157	1.160	1.162	1.165	1.167	1.168
80	1.137	1.143	1.146	1.149	1.151	1.154	1.156	1.159	1.161	1.162
85	1.132	1.137	1.140	1.144	1.146	1.149	1.151	1.154	1.156	1.157
90	1.127	1.132	1.135	1.139	1.141	1.144	1.146	1.149	1.151	1.152
95	1.122	1.127	1.130	1.134	1.136	1.139	1.141	1.144	1.146	1.147
100	1.117	1.122	1.125	1.129	1.131	1.134	1.136	1.139	1.141	1.142
105	1.111	1.117	1.120	1.123	1.125	1.128	1.130	1.133	1.135	1.136
110	1.106	1.111	1.114	1.118	1.120	1.123	1.125	1.128	1.130	1.131
115	1.101	1.106	1.109	1.113	1.115	1.118	1.120	1.123	1.125	1.126
120	1.096	1.101	1.104	1.108	1.110	1.113	1.115	1.118	1.120	1.121
125	1.091	1.096	1.099	1.103	1.105	1.108	1.110	1.113	1.115	1.116
130	1.085	1.091	1.094	1.097	1.099	1.102	1.104	1.107	1.109	1.110
135	1.080	1.086	1.088	1.092	1.094	1.097	1.099	1.102	1.104	1.105
140	1.075	1.080	1.083	1.087	1.089	1.092	1.094	1.097	1.099	1.100
145	1.070	1.075	1.078	1.082	1.084	1.087	1.089	1.092	1.094	1.095
150	1.065	1.070	1.073	1.077	1.079	1.082	1.084	1.087	1.089	1.090
155	1.059	1.063	1.068	1.071	1.073	1.076	1.078	1.081	1.083	1.084
160	1.054	1.059	1.062	1.066	1.068	1.071	1.073	1.076	1.078	1.079
165	1.049	1.054	1.057	1.061	1.063	1.066	1.068	1.071	1.073	1.074
170	1.044	1.049	1.052	1.056	1.058	1.061	1.063	1.066	1.068	1.069
175	1.039	1.044	1.047	1.051	1.053	1.056	1.058	1.061	1.063	1.064
180	1.033	1.039	1.042	1.045	1.047	1.050	1.052	1.055	1.057	1.058
185	1.028	1.033	1.036	1.040	1.042	1.045	1.047	1.050	1.052	1.053
190	1.023	1.028	1.031	1.035	1.037	1.040	1.042	1.045	1.047	1.048
195	1.018	1.023	1.025	1.030	1.032	1.035	1.037	1.040	1.042	1.043
200	1.013	1.018	1.021	1.025	1.027	1.030	1.032	1.035	1.037	1.038
205	1.008	1.013	1.015	1.020	1.022	1.025	1.027	1.030	1.032	1.033
210	1.008	1.008	1.011	1.015	1.017	1.020	1.022	1.025	1.027	1.028
212	1.002	1.002	—	—	—	—	—	—	—	—

TABLE 283. -RELATIVE ECONOMY OF FEED-APPARATUS.
(JACOBUS.)

Feed Water, how Supplied.	Relative Consumption of Coal.	Relative Economy Effected.
Direct-acting pump, feeding water at 60°, without a heater	1 000	0 0
Injector feeding water at 150° without a heater	985	1.5 per cent.
Injector feeding through a heater in which the water is heated from 150° to 200°	938	6.2 ..
Direct-acting pump, feeding water through a heater, in which it is heated from 60° to 200°	879	12.1 ..
Gearcd pump run from the engine, feeding water through a heater, in which it is heated from 60° to 200°	868	13.2 ..

TABLE 284. -WEIGHT OF SEDIMENT COLLECTED IN A STEAM-BOILER, FROM HARD WATER, EVAPORATED AT THE RATE OF 1000 GALLONS PER DAY

Solid Matter per Gallon Evaporated	Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated	Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated.	Solid Matter per Gallon Evaporated.	Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated.	Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated
Grains.	Lbs. Ozs.	Lbs. Ozs.	Grains.	Lbs. Ozs.	Lbs. Ozs.
1	0 23	0 13.7	15	2 23	12 13.7
2	0 46	1 11.4	20	2 13.7	17 23
3	0 69	2 9.1	25	3 0.1	21 6.9
4	0 91	3 6.9	30	4 1.	25 1.
5	0 11.4	4 4.6	35	5 1.	30 1.
6	0 13.7	5 2.3	4	5 1.	35 1.
7	1 0	6 0	5	6 1.	40 1.
8	1 2.3	6 13.7	6	7 1.	45 1.
9	1 4.6	7 11.4	7	8 1.	50 1.
10	1 6.9	8 9.1	8	9 1.	55 1.

Flow of Steam through Pipes.

TABLE 286.—FLOW OF STEAM THROUGH PIPES.
("Steam.")

Initial Pressure per Square Inch.	Diameter of Pipe in Inches. Length of each Pipe, 240 Diameters.						
	$\frac{3}{4}$	1	1 $\frac{1}{2}$	2	2 $\frac{1}{2}$	3	4
	Weight of Steam per Minute in Pounds, with One Pound Fall of Pressure.						
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	1.16	2.07	5.7	10.27	15.45	25.38	46.85
10	1.44	2.57	7.1	12.72	19.15	31.45	48.05
20	1.70	3.02	8.3	14.94	22.49	36.94	68.20
30	1.91	3.40	9.4	16.84	25.35	41.63	76.84
40	2.10	3.74	10.3	18.51	27.87	45.77	84.49
50	2.27	4.04	11.2	20.01	30.13	49.48	91.34
60	2.43	4.32	11.9	21.38	32.19	52.87	97.60
70	2.57	4.58	12.6	22.65	34.10	56.00	103.37
80	2.71	4.82	13.3	23.82	35.87	58.91	108.74
90	2.83	5.04	13.9	24.92	37.52	61.62	113.74
100	2.95	5.25	14.5	25.96	39.07	64.18	118.47
120	3.16	5.63	15.5	27.85	41.93	68.87	127.12
150	3.45	6.14	17.0	30.37	45.72	75.09	138.61

Initial Pressure per Square Inch.	Diameter of Pipe in Inches. Length of each Pipe, 240 Diameters.						
	5	6	8	10	12	15	18
	Weight of Steam per Minute in Pounds, with One Pound Fall of Pressure.						
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	77.3	115.9	211.4	341.1	502.4	804	1177
10	95.8	143.6	262.0	422.7	622.5	996	1458
20	112.6	168.7	307.8	496.5	731.3	1170	1713
30	126.9	190.1	346.8	559.5	824.1	1318	1930
40	139.5	209.0	381.3	615.3	906.0	1450	2122
50	150.8	226.0	412.2	665.0	979.5	1567	2294
60	161.1	241.5	440.5	710.6	1046.7	1675	2451
70	170.7	255.8	466.5	752.7	1108.5	1774	2596
80	179.5	269.0	490.7	791.7	1166.1	1866	2731
90	187.8	281.4	513.3	828.1	1219.8	1951	2856
100	195.6	293.1	534.6	862.6	1270.1	2032	2975
120	209.9	314.5	573.7	925.6	1363.3	2181	3193
150	228.8	343.0	625.5	1009.2	1486.5	2378	3481

Mr. Babcock gives the following formula for the flow of steam through pipes :—

$$W = 300 \sqrt{\frac{D(p_1 - p_2)d^5}{L\left(1 + \frac{3.6}{d}\right)}} \quad (19)$$

W = weight of steam in pounds

d = diameter of pipe in inches.

D = density or weight per cubic foot of the steam.

p_1 = initial pressure.

p_2 = pressure at end of pipe.

L = length of pipe in feet

The Table 286 gives, approximately, the weight of steam which would flow through a straight smooth pipe, of which the length is equal to 240 diameters, with one pound fall of pressure

For any other given fall of pressure multiply the tabular weight by the square root of the given fall of pressure.

For any other given length of pipe, divide 240 by the given length in diameters, and multiply the tabular values by the square root of the quotient, to give the flow for one pound fall of pressure.

Conversely, divide the given length by 240, to find the fall of pressure for the flow given in the Table.

The loss of head due to generation of the velocity of flow, and the friction of the steam entering the pipe, is about equal to the resistance of a length of pipe equal to the quotient of 114 diameters, divided by $\left(1 + \frac{3.6}{d}\right)$ in which d is the diameter in inches. For the sizes given in the Table, the corresponding lengths are as follows —

Diameter in inches.	Length in Diameters.	Diameter in inches.	Length in Diameters.	Diameter in inches.	Length in Diameters.
$\frac{3}{4}$	20	3	52	10	84
1	25	4	60	12	88
$1\frac{1}{2}$	34	5	66	15	92
2	41	6	71	18	95
$2\frac{1}{2}$	47	8	79		

The resistance of a globe-valve is equal to that at the entrance of the pipe; and that at an elbow is equal to two thirds of that of a globe-valve. The equivalent lengths respectively are —

globe-valve and three elbows would be equivalent to $(120 + 60 \text{ (entrance)} + 60 \text{ (globe-valve)} + (40 \times 3) =) 360$ diameters in length. By the rule above given, $(360 : 240 =) 1\frac{1}{2}$ lbs. is the fall or loss of pressure for the tabulated flow. Or, it would deliver $(1 \div \sqrt{1\frac{1}{2}} =) \cdot 816$, or 81.6 per cent. of the steam with the same loss (1 lb.) of pressure.

Coverings for Steam-Boilers and Steam-Pipes.

The efficiency of different substances for the prevention of radiation of heat, varies generally in the inverse ratio of their conducting power for heat. From the results of experiment it appears that the rates of condensations of steam in a naked pipe, a pipe coated with a cement, and a pipe coated with hair-felt, were proportionally as 100, 67, and 27. According to Dr. Emery, the relative efficiency of various substances and coverings, is as given in Table 287.

TABLE 287.—RELATIVE EFFICIENCY OF NON CONDUCTORS (Emery.)

Substance	Relative Efficiency.
Wood felt	1 000
Mineral wool, No. 2	832
" " with tax	715
Sawdust	680
Mineral wool, No. 1	676
Charcoal	632
Pine wood, across fibre	553
Loam, dry and open	550
Slacked lime	480
Gas-house carbon	470
Asbestos	363
Coal ashes	345
Coke in lumps	277
Air space undivided	136

The relative loss of heat from steam-pipes naked and clothed with wool or hair-felt, in several thicknesses, is given in Table 287. The steam pressure is taken at 75 lbs. per square inch; and the temperature of the air at 60° F. The horse-power mentioned in the Table is the standard for steam-boilers favourably received in America, according to which one horse-power is measured by the evaporation of 30 pounds of water per hour, at a working pressure of 70 lbs. per square inch from 100° F. temperature.

TABLE 238.—LOSS OF STEAM BY CONDENSATION IN PIPES.
("Steam.")

OUTSIDE DIAMETER OF PIPE.															
Thickness of Covering	Two inches.			Four inches.			Six inches.			Eight inches.			Twelve inches.		
	Loss per Lineal Foot per Hour	Ratio of Loss	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour	Ratio of Loss	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.
Naked.	319.0	1.00	132	330.8	1.00	75	624.1	1.000	46	729.8	1.000	40	1077.4	1.000	26
1	100.0	.46	288	180.9	.46	160	187.2	.300	164	219.6	.301	132	301.7	.330	92
2	66.7	.30	441	117.2	.30	247	111.0	.178	261	128.8	.176	225	185.3	.172	157
3	48.8	.20	602	78.9	.18	302	66.2	.106	438	75.2	.103	385	98.0	.091	294
4	28.4	.18	1020	44.7	.11	648	41.2	.066	703	46.0	.063	430	60.8	.056	480
5	19.8	.09	1464	28.1	.07	1031	33.7	.054	800	34.8	.047	545	45.2	.042	642

RAILWAYS.

THE lengths of lines in the United Kingdom open for traffic on the 31st December, 1889, were in

	Miles Open.
England and Wales	14,034
Scotland	3,118
Ireland	2,791
	<hr/> 19,943

or, as a round number, say, 20,000 miles.

The total paid-up capital, including loans and debenture stock, was £876,595,166, or £43,960 per mile open.

The number of passengers conveyed in the year 1889 were :—

1st class	30,074,810 or	3·88 per cent.
2nd "	62,687,927 "	8·407 "
3rd "	682,420,336 "	88·05 "
Total	775,183,073	100·00

In goods traffic there were conveyed—

211,810,551 tons of minerals, or	71·20 per cent.
85,695,947 " " general merchandise	28·80 "

297,506,498	100·00
-------------	--------

The number of miles travelled by trains were as follows :

	Miles.
Passenger trains	161,082,875
Goods and mineral trains	138,941,233
Total	303,116,953

The total includes 3 092,845 miles travelled by mixed trains.

The receipts were as follows :—

Gross receipts from passenger traffic	£32,630,724 or 42·4 per cent.
Do. Goods "	41,086,333 " 53·3 "
Miscellaneous receipts	3,307,960 " 4·3 "
	<hr/> £77,025,017 100·0

or about £3,851 per mile open, or 6s. 1d. per train-mile run.

The total working expenditure was £40,094,116, or 52 per cent. of the receipts.

The rolling stock, on December 31, 1889, was as follows :—

Locomotives (fully three-fourths of a locomotive per mile open)	15,924
Passenger carriages	36,137
Other passenger train stock	13,501
Waggons	603,260
Sundry carriages and waggons	14,335
Passenger and goods trains carrying stock (or about 35½ vehicles per locomotive; or about 28½ vehicles per mile open)	567,233

The average number of train-miles run per locomotive was 19,000.

The standard forms of rails are the bull-headed, the double-headed, and the flange or flat-foot rails. Of the rails used on British and Irish railways, the following are the principal dimensions :—

TABLE 289.—RAILWAY RAILS AND SLEEPERS.

	Bull-headed Rails.	Double-headed Rails.	Flange Rails
Weight of rail per yard	30 lb. to 80 lb.	82 lbs.	74 lbs., 70 lbs.
Height	4¾ ins. to 5½ ins.	5½ ins., 5½ ins.	4¾ ins. to 4½ ins.
Width of head	2½ ins. to 2½ ins.	2½ ins.	2½ ins., 2½ ins.
Width of flange			5 ins.
Thickness of web	1½ in. to 1½ in.	1½ in. to 1½ in.	1 in. to 1 in.
Length of bars	24 ft. to 32 ft.	24 ft. to 30 ft.	24 ft. to 20½ ft.
Section of sleepers	10 × 5 ft. to 12 × 6 ft.	10 × 5 ft.	10 × 5 ft.
Distance of sleepers apart	2 ft. 6 ins. to 3 ft. 1 in.	2 ft. 3 in. to 2 ft. 10 in.	3 ft.
Weight of chair	39 lbs. to 55 lbs.	31 lbs. to 40 lbs.	...

Large express locomotives weigh in working order from 40 tons to 50 tons. The latest Midland Railway express engine weighs, in working order, 43 tons, of which the driving weight, on a single pair of wheels, is 17½ tons. The area of the grate is 19.6 square feet: the heating surface is 1,100

square feet. The tender weighs, empty, 12 tons, and 30 tons when loaded with $3\frac{1}{2}$ tons of coal, and 3,250 gallons of water. The working steam pressure in the boiler is 160 lbs. per square inch. The cylinders are $18\frac{1}{2}$ inches in diameter with a stroke of 26 inches. The driving wheels, single, are $7\frac{1}{2}$ feet in diameter, with a bogie in front. The total wheel-base of the engine and tender together is about 43 feet on the rails. On the London and Nottingham traffic, the average gross load weighs from 170 to 215 tons, or from 9 to 12 carriages. The time ball speed is $58\frac{1}{2}$ miles per hour; the longest continuous run is 124 miles, and from 20 lbs. to 23 lbs. of Derbyshire coal is consumed per mile-run.

Parliamentary trains, calling at all the stations, run at an average speed of from 19 to 28 miles per hour. Express goods trains make a speed of from 20 to 25 miles per hour. The speed of coal trains is limited, as far as is practicable, to 15 miles per hour.

Coal trains generally consist of from 30 to 35 waggons, weighing from 5 tons to $5\frac{1}{2}$ tons each, and carrying 8 tons of coal. At this rate, the total load of coal for 35 waggons weighs 280 tons; add the weight of the break van at the end of the train, 10 tons, 17 cwt., and the maximum gross weight of the train is 483 tons, 7 cwt.

A 6 coupled locomotive, suited for taking this train on the Great Northern Railway, has $5\frac{1}{2}$ feet wheels, $17\frac{1}{2}$ inch cylinders with a 26 inch stroke, with 140 lbs. pressure in the boiler; weighing, in working order, 87 tons, and with the tender full of water and coal, 68 tons. The engine, tender, and train together weigh 551 tons. Such trains are taken at a speed of 18 miles per hour; ascending inclines of 1 in 178 at a speed of 10 miles per hour, consuming 45 lbs. of coal per mile. With more powerful engines, having 19 inch cylinders, trains of 45 loaded coal waggons are taken.

Six-coupled goods engines, working at full power, exert a tractive force of from 5 tons to 6 tons at the rails. With a tractive force of 10 lbs. or 12 lbs., 1 ton of gross weight can be drawn on a level straight line at a speed of 10 miles per hour. At 60 miles per hour, the tractive force, with sharp curves and high winds, may amount to 45 lbs. for 1 ton.

Railway Gauges.

The standard gauge of railways in Great Britain is 4 feet $8\frac{1}{2}$ inches. The same gauge is adopted in some other countries. See Table 290.

RAILWAY GAUGES.

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TABLE 290.—GAUGES OF THE PRINCIPAL RAILWAY SYSTEMS IN THE WORLD.

	Ft.	Ins.
Great Britain, standard gauge	4	8½
Ireland, standard gauge	5	3
Central Europe, prevailing gauge	4	8½
Russia, standard gauge	5	0
Norway	4	8½
	3	6
Spain and Portugal, standard gauge	5	6
Antwerp and Ghent	2	3
India, prevailing gauge	7	6
„ metre gauge	3	3½
„ Arcotum and Conjeveram	3	6
Japan	3	6
Egypt	4	8½
	5	6
Canada	4	8½
	3	6
Mexico	4	8½
	3	0
	4	8½
prevailing gauges	4	9
United States of America	6	0
	5	0
	3	0
	2	0
	5	6
Chili	4	8½
	4	2
	3	6
Brazil	5	6
	3	3
South Australia	3	3
	3	6
New South Wales	4	2½
Victoria	5	3
New Zealand	5	3
	3	6

In the United Kingdom there are a few local railways of less than the national gauge

	Feet.	Inches.
Festiniog	1	11½
Talylyn	2	6
Dinas and Snowdon, Ballymena and Larne, and others	3	0

The Way: Rails, Chairs, and Sleepers.

The bull-headed rail is laid on most of the railways in Great Britain. The double-headed rail, reversible, is also in use. In Ireland, both are in use. They weigh from 82 lbs. to 86 lbs. per lineal yard. The heads are from 2½ to 2¾ inches wide; and the height of rail is from 5½ to 5¾ inches. The rails are of steel, rolled in bars mostly 30 feet in length. They are carried in cast-iron chairs weighing from 31 lbs. to 55 lbs. each, spiked to transverse sleepers of Baltic red wood generally 10 inches wide, 5 inches deep, and 9 feet long.

Cost of 1 Mile of Single Line of Way on a first class Railway.

	£	s	d
Steel rails, bull-headed, 30 feet long, 85 lbs. per yard, 133½ tons at £5	667	10	0
Chairs, 3,872, at 50 lbs.; 86½ tons at £3	259	10	0
Fish-plates, steel chip, 352 pairs at 10 lbs. — 6½ tons, at £8	50	0	0
Bolts and nuts, 1,408 at 1½ lbs.; 1 ton at £9 10s	9	10	0
Spikes, 7,744 at 1½ lbs.; 4½ tons at £7 10s.	31	17	0
Trenails, solid oak, 7,744 at £2 10s per 1,000	19	7	0
Keys, oak, 3,872 at £4 per 1,000	15	9	0
Sleepers, creosoted, 1,936 at 4s.	387	4	0
Labour, 1,760 yards at 1s. 6d.	132	0	0
Total cost of laying	£1,572	8	0
Taking credit for old materials in case of re-laying, the net cost of relaying is, say	£858	0	0

To find the position of the Centre of Gravity of a locomotive in the horizontal sense, when the loads on the rails at the axle and their distances apart are given.

1. *Four-wheeled locomotive.* Multiply the load at the driving axle in tons by the length of the wheel base in feet

and divide by the total weight in tons. The quotient is the horizontal distance, in feet, of the centre of gravity from the other axle.

When the loads at the axles are equal, the centre of gravity lies half-way between them.

2. *Six-wheeled locomotive.* Multiply the loads at the leading and trailing axles, in tons, by their respective distances from the middle axle in feet; divide the difference of the products so found by the total weight in tons. The quotient is the horizontal distance, in feet, of the centre of gravity from the middle axle, measured towards the axle for which the greater product was found.

When the products are equal, the centre of gravity lies exactly over the middle axle.

3. *Locomotives having more than six wheels.* Select a middle axle. Multiply the loads at the axles in front of the selected axle by their distances respectively from this axle; do likewise with the axles behind the selected axle. Find the difference of the sums of the products in front and behind the selected axle; and divide it by the total weight in tons. The quotient is the distance horizontally, in feet, of the centre of gravity from the selected axle, measured in the direction for which the greater sum of the products was found.

Tractive Power and Resistance on Railways.

For two cylinders of equal diameters, the equivalent tractive force, as at the rails for a given effective mean pressure in the cylinders, may be calculated by means of the formula —

$$T = \frac{d^2 L p}{D} \quad (1)$$

The equivalent effective mean pressure in the cylinders required for a given tractive force as at the rails is by formula —

$$p = \frac{DT}{d^2 L} \quad (2)$$

d — diameter of cylinder, in inches.

L — length of stroke, in inches.

D — diameter of driving wheels, in inches.

p — effective mean pressure, in pounds per square inch.

T — equivalent tractive force, as at the rails, in pounds.

If it be assumed that the work done in the second cylinder of a compound locomotive is equal to that done in the first

TABLE 291.—RESISTANCE OF PASSENGER TRAINS.

Ascending Gradients.	CONDITIONS. { A good sound road A straight line. An average side-wind Engine, tender, and train in good working order, with grease lubrication.						
	Speed, in Miles per Hour						
	10	20	30	40	50	60	70
Total Resistance as at the Rails, in Pounds per Ton.							
Level	Lbs. 8·6	Lbs. 10·3	Lbs. 13·2	Lbs. 17·3	Lbs. 22·6	Lbs. 29	Lbs. 36·6
1 in 40	64	66	69	73	79	85	93
1 " 60	46	48	50	53	60	66	74
1 " 80	36	38	41	45	51	57	65
1 " 100	31	33	36	40	46	51	59
1 " 150	24	26	28	32	38	44	51
1 " 200	20	22	25	29	34	40	48
1 " 250	18	20	22	26	32	38	46
1 " 300	16	18	21	25	30	36	44
1 " 500	13	15	18	22	27	33	41
1 " 800	11	13	16	20	25	32	39
1 " 1000	11	12	15	19	25	30	39
Level	8·6	10·3	13·2	17·3	22·6	29	36·6

Note. Fifty per cent. of the resistance as on a straight level way may be added for cases of frequent curves, of or under one mile in radius, in connection with strong side and head winds.

The general dimensions, weights, and capacity of the standard carriage stock and waggon stock of the Midland Railway, are given in Tables 295 and 296, page 543.

Supposing an engine and tender, weighing together 40 tons, and exerting a given tractive force, takes 40 loaded carriages, weighing 360 tons, at 20 miles per hour on a level, the loads which it could take if it exerted the same tractive force at higher speeds, would be proportionately as follows —

At 20 miles per hour, 40 carriages weighing 360 tons.						
" 30	"	"	30	"	"	200 "
" 40	"	"	21	"	"	144 "
" 50	"	"	15	"	"	106 "
" 60	"	"	11	"	"	75 "

The influence of rising inclines is exemplified as follows :

If an engine and tender, weighing together 40 tons, draw a maximum train of 42 loaded carriages, weighing 420 tons, at 20 miles per hour on a level, it would draw on the following loads at the same speed up the annexed inclines :—

Level	.	.	.	42 carriages, weighing 420 tons.
Incline, 1 in 600	.	.	.	34 " " 340 "
" " 300	.	.	.	27 " " 270 "
" " 150	.	.	.	20 " " 200 "
" " 100	.	.	.	15 " " 150 "
" " 75	.	.	.	12 " " 120 "
" " 50	.	.	.	9 " " 90 "
" " 40	.	.	.	6 " " 65 "
" " 30	.	.	.	5 " " 45 "
" " 20	.	.	.	3 " " 24 "
" " 10	.	.	.	nil " nil.

The speed of railway trains may be calculated in terms of the number of revolutions of the driving wheels of the locomotive in a given number of seconds. Let,—

r = number of revolutions in the given time.

t = time in seconds.

d = diameter of driving wheels, in feet.

v = velocity or speed in miles per hour.

The number of turns per hour is $\left(r \times \frac{60}{t} \times 60 \text{ minutes} \right)$

$$\frac{3600r}{t}$$

The number of turns per mile is $\left(\frac{5,280 \text{ feet}}{3.1416 d} = \right)$

$$\frac{1680.7}{d}$$

The speed in miles per hour is equal to (a) divided by (b) or, by reduction,—

$$v = \frac{2142 d r}{t}$$

The Table 292 gives multipliers in the 3rd column, by use of which the speed of a train may be calculated in terms of the diameter of the driving wheel, column 1, for any given number of revolutions of the wheels in a given number of seconds. The speeds in the 3rd column are those due to one revolution in one second; and the speed due to the given diameter of wheel is to be multiplied by the observed number of turns, and the product divided by the time of observation in seconds. Or, thus,—

Speed for 1 turn in 1 second \times $\frac{\text{number of turns observed}}{\text{time of observation in seconds}}$

For example, a 5 feet driving wheel makes 20 revolutions in 10 seconds. The multiplier in the 3rd column for a 5-foot wheel is 10.71; and the speed is $\left(10.71 \times \frac{20}{10} =\right)$ 21.42 miles per hour

TABLE 292.—MULTIPLIERS FOR SPEED OF RAILWAY TRAINS

Diameter of Driving Wheels.	Number of Revolutions in One Mile.	Speed for One Revolution in One Second.	Diameter of Driving Wheels.	Number of Revolutions in One Mile.	Speed for One Revolution in One Second.
1	2	3	1	2	3
Ft. Ins.	Revolutions.	Miles per Hour	Ft. Ins.	Revolutions.	Miles per Hour
3 0	560.2	6.42	6 9	249.0	14.46
3 3	517.1	6.96	7 0	240.1	14.99
3 6	480.2	7.50	7 3	231.8	15.53
3 9	448.2	8.03	7 6	224.1	16.06
4 0	420.2	8.57	7 9	216.9	16.60
4 3	395.4	9.10	8 0	210.1	17.14
4 6	373.5	9.64	8 3	203.7	17.67
4 9	353.8	10.17	8 6	197.7	18.21
5 0	336.1	10.71	8 9	192.7	18.74
5 3	320.1	11.25	9 0	186.7	19.28
5 6	305.6	11.78	9 3	181.7	19.81
5 9	292.3	12.32	9 6	176.9	20.35
6 0	280.1	12.85	9 9	172.4	20.88
6 3	268.9	13.39	10 0	168.1	21.42
6 6	258.6	13.92			

The relations of the speed in miles per hour and the corresponding time running one mile, are expressed by the formulas (5) and (6). There are $(60 \times 60 =)$ 3,600 seconds in an hour, and the time of running one mile is equal to the quotient of 3,600 divided by the speed in miles per hour. Also the speed is equal to the quotient of 3,600 divided by the time of running one mile. Or,

$$t = \frac{3,600}{s} \quad (5)$$

$$s = \frac{3,600}{t} \quad (6)$$

t = time running one mile, in seconds.

s = speed in miles per hour.

TABLE 294.—BULK AND WEIGHT OF GOODS (*continued*)

Number of Kind of Goods.	Description of Goods carried.	Cubic Feet per Ton.	Weight per Cubic Foot.
No.		Cubic Feet.	Pounds.
CLASS 2 (<i>continued</i>).			
12	Full-pressed cotton	70	
13	Flax and hemp	70	
14	Groceries	60	
15	Grains and seed	60	
16	Twist	60	
17	Sugar	56	
18	Soap	56	
19	Firewood	56	
20	Salt	51	
21	Lime	51	
22	Dry fruits	50	
CLASS 3.			
23	Molasses	43	
24	Seed cotton	43	
25	Mowra (flowers which pro- duce spirit)	45	
26	Timber	45	
27	Ghee (clarified butter)	40	
28	Oil	40	
29	Piece goods	40	
30	Rape	40	
31	Beer and spirits	36	
32	Coal	28	
33	Paper	28	
34	Tobacco	28	
35	Opium	26	
36	Machinery	25	
CLASS 4.			
37	Cutlery	20	
38	Potash	20	
39	Sand	20	
40	Colours	18	
41	Bricks	17	
42	Stone	15	
43	Metal	15	

TABLE 295. CARRIAGE STOCK, MIDLAND RAILWAY.

Carriage.	Length of body.	Compartmenta.	Number of passengers.	Weight of Vehicle.		Price.
				Tons. Cwts.	£	
6-wheel bogie com- posite	54	3 first class, 4 third class, 1 luggage=8	58	23 0	1007	
4-wheel bogie com- posite	45	3 first class, 3 third class, 1 luggage=6	48	18 10	708	
4-wheel bogie, third class	43	7 third class	70	17 15	620	
4-wheel bogie com- posite	40	2 first class, 3 third class, 1 luggage=6	42	17 5	604	
6-wheel first class	30	4 first class	24	10 12	516	
6-wheel composite	31	2 first class, 2 third class, 1 luggage=5	32	11 10	450	
4-wheel third class	31	5 third class	50	10 7	390	

TABLE 296. WAGON STOCK, MIDLAND RAILWAY.

Wagon.	External Dimensions over Corner Pillars.		Internal Dimensions.			Load to Carry.	Weight of Wagon.	Price.
	Length.	Width.	Length	Width	Height above floor.			
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Tons.	Tons Cwts.	£
Covered goods	14 11	7 5	14 2	6 10	5 10½	8	6 3	72
High sided, for goods or coal	14 11	7 5	14 6	7 0	2 10	8	5 2	6
Low sided	14 11	7 5	14 6	7 0	1 9	8	4 14	61
Cattle wagon	18 6	8 0	17 9	7 4	7 0½	8	6 0	86

Electrical Propulsion on Railways.

In consequence of the number of stages between the generation of steam in the stationary boilers and the hauling of the train, the efficiency of electric propulsion is relatively small. There is, first, the power consumed in driving the engine and dynamo; then, the dynamo cannot give in electrical power all the mechanical power applied to it; then there is the loss by line resistance and leakage; and the loss in the motor. These losses were such, in one case, that the

efficiency of the entire plant was only 15·1 per cent. In another case, the efficiency averaged 25 per cent. The cost for power by electric agency is considered to be about five times that of direct steam power.

TRAMWAYS.

The total length of tramway lines in the United Kingdom open for public traffic on the 30th June, 1889, was 949 miles, distributed as follows :—

	Miles open
England	758
Scotland	81
Ireland	110
	<hr/> 949

Of this length, 407½ miles were double line, and 541½ miles were single line : respectively 42 per cent. and 58 per cent.

The total capital expended at June 30, 1889, amounted to £13 664,591 ; or £14,400 per mile open.

The working stock was as follows :—

27,060 horses, or	28½ horses per mile open.
539 locomotives	57 locomotives " "
3,645 cars, or	3 84 cars " "

62,041,013 miles were run by cars.

The gross receipts for the year were £2,980,224 ; or £3·1 per mile open ; or 11½d. per car mile run.

The working expenses were £2,266,681, or 76 per cent. of the receipts ; or 8½d. per mile run.

Flat foot girder rails of steel, weighing from 80 lbs. to 90 lbs. per yard, are now most commonly laid. They are about 6 inches in height, and from 5 inches to 6 inches wide at the flange-base.

Cars capable of holding 20 passengers inside, and 22 outside, weigh about 2½ tons each. The gross weight, fully loaded, is 5½ tons. The body of the car is 15½ feet in length, 6 ft. 8 inches wide, outside measurement. The total length of the car is 21½ feet, allowing 3 feet at each end for the platform.

The average resistance to traction is about 30 lbs. per ton of car and its load. When the rails are wet and clean, straight and new, a minimum of 15 lbs. per ton may be reached. An occasional maximum resistance of 60 lbs. per ton may be reached ; the augmentation being due mostly to the closing of the grooves of the rails.

*Cost per mile, single line, of sample of Tramway: girder rail
80 lbs. per yard, 7 inches high.*

	£	s.	d.
Steel rails, 80 lbs. per yard, 125½ tons, @ £8 14s.	1,094	0	6
Wrought-iron fish plates, 4½ tons, @ £8	38	0	0
" " bolts and nuts, 9 cwt., at 11s	4	19	0
Lifting and carting away, 522 cubic yards @ 1s. 9d.	45	13	6
Excavation, &c., 1,108 cubic yards, @ 2s.	110	16	0
Portland cement concrete, 6 inches thick, 782 cubic yards, @ 17s.	664	14	0
Laying tramway, 1,760 yards, @ 1s. 8d.	146	13	4
Total for the way	2,104	16	4
Paving, &c., 2,836 square yards, @ 7s. 3d.	1,028	1	0
Paving in cement and sand, next rails, 1,564 square yards, @ 7s. 7d.	593	0	4
Grouting joints of sets with bitumen, 4,400 square yards, @ 1s. 3½d.	284	3	4
Total for paving	1,905	4	8
Total for way and paving	4,010	1	0

Steam Power on Tramways.

Kitson & Co.'s engines on the Birmingham Central Tramways weigh, with water and coal, from 9 to 10 tons. They draw a car holding 60 passengers. On the same line, the engines of the Falcon Company have 8 inch cylinders, with 14 inches of stroke, and 2½ feet wheels. In drawing two loaded cars weighing together 18½ tons, at a speed of 6 miles per hour, on a gradient of 1 in 25, they indicated 40 horsepower, consuming from 8 to 9 pounds of coke per mile.

Compressed-Air Tramway Engines.

Mekarski's system of employing compressed air, heated by an admixture of steam, is in operation on the Naples tramways. The efficiency of the air-compressors is 76 per cent, in volume of air delivered—one kilogramme, or 2.205 pounds of air, compressed to a pressure of 426 lbs. per square inch, supplies energy equivalent to 90,375 foot-pounds, and 100 kilogrammes, or 220 pounds of compressed air, is sufficient to propel a car of 8 tons loaded weight for a distance of from 7½ to 8 or 9 miles. The cars have seats for 19 persons, a platform for 15 or 16 at one end, and the heater and the driver's cab at the other end. The total length is 23½ feet, and the

width is $7\frac{1}{2}$ feet. The weight of the car is 6 tons empty, 8 tons full of which the adhesion weight is $4\frac{1}{2}$ tons. It is compressed air contained in 10 cylindrical reservoirs, arranged transversely underneath the platform, connected by pipes in two sets, to form a working and a reserve battery, having respectively 70 and 28 cubic feet of capacity; together 98 cubic feet, and holding, when charged, 220 pounds of compressed-air. The working cylinders are outside, $5\frac{1}{2}$ inches in diameter, with a stroke of 10 inches, the compressed air cut off at one-third. The driving wheels are $27\frac{1}{2}$ inches in diameter. The heater has a capacity of 28 gallons, and the water is heated to 300° F. by the injection of steam before starting. The consumption of compressed air varies from 23 pounds to $28\frac{1}{2}$ pounds per mile. The working cost is at the rate of about 6d. per mile-run.

From the results of trials made by D. K. Clark of one of Hughes & Lancaster's low-pressure compressed-air tramcars propelled by means of four single-acting 5-inch cylinders, 3 inches stroke, it appears that the consumption of compressed air was at the rate of 30 pounds per mile-run for a car. The car, with passengers weighed $4\frac{1}{2}$ tons; and the work done was at the rate of 22,070 foot-pounds per pound of air. The maximum working pressure of compressed air was 132 lb. per square inch.

Electrical Propulsion on Tramways.

The Bessbrook and Newry Tramway, 3 miles long, has an average gradient of 1 in 80, and a maximum gradient 1 in 50; and is to a 3 feet gauge. It is worked by electric power. Two passenger cars, 33 feet and 21 feet 8 inches long, are each provided with a motor. The longer car weighs $8\frac{1}{2}$ tons, comprising 2 tons, 1 cwt. 1 quarter, the weight of the dynamo, bed-plate, armature, and accessories. The shorter car is similar to the longer, and there is a third passenger car 33 feet long, weighing $5\frac{1}{2}$ tons. The generator is worked by fall of water 28 feet high. There are two generating dynamos for a normal output of 250 volts, 72 amperes, at a speed of 1,000 revolutions per minute, for which the electrical efficiency is 92.2 per cent, and the commercial efficiency 90.4 per cent. The conductor is of channel steel, laid midway between the rails or under insulators. The circuit is completed by the rails of the permanent way, which are uninsulated. The locomotive car is fitted with an Edison-Hopkinson dynamo motor. A speed of one mile per hour corresponds to 10 revolutions of the dynamo-axle per minute. Three trains, having six trucks, four trucks, and no trucks respectively,

and weighing 28·4 tons, 21·4 tons, and 8·8 tons, including the weight of the locomotive, were tried for efficiency. The leading results are given in Table 297, and the percentages in Table 298.

TABLE 297.—BESSBROOK AND NEWRY TRAMWAYS.
RESULTS OF ELECTRICAL TRACTION.

Items.	First Journey.	Second Journey.	Third Journey.
	Tons. Cwts. Qrs.	Tons. Cwts. Qrs.	Tons. Cwts. Qrs.
Gross load	28 12 0	21 16 0	8 10 0
Average speed, in miles per hour	5	7·2	11·1
Total energy of water, in foot-pounds	60,291,000	40,860,000	27,592,000
Total electrical energy developed by generator, in foot-pounds	45,871,000	21,516,000	2,382,400
Total mechanical energy developed by motor, in foot-pounds	24,938,200	11,493,500	7,170,900
Sum of electrical losses, in foot-pounds	12,408,800	5,841,000	2,174,700
Loss in generator, in foot-pounds	3,348,000	1,735,800	801,000
leakage	7,420,800	4,029,900	775,500
" resistance of line, in foot-pounds	3,019,500	1,996,900	287,100
" motor, in foot-pounds	4,098,000	1,791,900	320,000
Total work done against gravity	11,807,400	7,550,800	2,858,800
" friction	600,800	8,100,000	4,315,800
Average tractive forces, exclusive of gravity, in pounds per ton	28·0	97·4	97·1

TABLE 298.—BESSBROOK AND NEWRY TRAMWAYS.
PERCENTAGE DISTRIBUTION OF POWER.

Items.	1st Journey.		2nd Journey.		3rd Journey.	
	Water Power.	Total Power of Generator.	Water Power.	Total Power of Generator.	Water Power.	Total Power of Generator.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Water power	100·0		100·0		100·0	
Generator power	59·5	100·0	52·3	100·0	33·9	100·0
Net motor power	41·3	69·4	27·0	52·0	20·1	70·8
Loss in generator	58·5	9·5	47·7	48·0	69·9	8·6
" leakage	2·8	3·3	2·5	4·8	2·8	8·2
" line resistance	8·0	10·6	3·2	6·0	1·0	2·4
" in motor	6·8	11·4	4·4	8·3	1·2	3·2

The Parking Road section of the North Metropolitan Tramways is worked by electrical power by contract, charged for the rate of about $1\frac{1}{2}d.$ per car mile run, including the wages of the driver.

Resistance to Traction on Common Roads.

(F. V. Greene.)

WAY	Pounds per ton
Iron	10 lbs
Asphalte	15 "
Wood	21 "
Best stone blocks	33 "
Inferior stone blocks	50 "
Average cobble stone	90 "
Macadam	100 "
Earth	200 "

STEAM-SHIPS.

The gross register tonnage of a ship is reckoned at the rate of 100 cubic feet of capacity per ton, by the formula —

$$\text{Register tonnage} = \frac{C \cdot L \cdot B \cdot D}{100} \quad (1)$$

L — inside length on the upper deck from the plank at the stem to the plank at the stern, in feet.

B — inside main breadth from ceiling to ceiling, in feet.

D — inside midship depth from the upper deck to the ceiling at the limber strake, in feet.

C — a constant, the values of which are as follows:—

	C
Sailing ships	70
Steam vessels and clippers	
} Ships of 2 decks	65
} Ships of 3 decks	68
Yachts	
} Above 60 tons	50
} Under 60 tons	45

The values thus obtained express the entire cubical capacity of the ship. Deductions are allowed for buildings erected for the shelter of passengers only, for crew space at the rate of 72 cubic feet per man, and propelling space. This third item for screw steamers, is taken as 32 per cent. if the content is 13 per cent. and under 20 per cent. of the tonnage; if the space is smaller than 13 per cent. and

than 20 per cent., deduct 32 per cent., or $1\frac{1}{2}$ times the content. For paddle-steamers, deduct 37 per cent., if the content is 20 per cent. and under 30 per cent.; if the space is smaller than 20 per cent. or larger than 30 per cent., deduct 37 per cent., or $1\frac{1}{2}$ times the content.

Builder's measurement is computed in terms of the length and the breadth by the formula:—

$$\text{Tonnage} = \frac{(L - 60 B) 1.5 B}{94} \quad (2)$$

L = length measured from the back of the main stern post to a vertical from the fore part of the main stem under the bowsprit, in feet

B = the extreme breadth to the outside planking, exclusive of doubling planks, in feet.

Resistance of Ships.

The thrust on the collars of the propeller shaft is a measure of the power actually exerted for the propulsion of the vessel. Let P = the thrust or pressure of the propeller against the thrust bearing in pounds; and S = the speed of the ship in feet per minute; the effective horse-power is,—

$$\frac{S \times P}{33,000}$$

Taking it as two-thirds of the indicator power, which is a usual proportion, $\frac{2}{3}$ I. H. P. = $\frac{S \times P}{33,000}$; and

$$P = \text{I. H. P.} \times \frac{22,000}{S} \quad (3)$$

The effective indicator horse-power required to propel a steam-ship is given by the following formulæ:—

$$\text{Eff. I. H. P.} = \frac{D^3 \times S^3}{C} \quad (4)$$

$$\text{Eff. I. H. P.} = \frac{A \times S^3}{K} \quad (5)$$

I. H. P. = effective indicator horse-power, or the net indicator power for propulsion.

D = displacement, in tons.

S = speed in knots per hour

A = immersed mid ship section, in square feet.

C = a constant.

K = a constant.

The results obtained by means of these formulae are taken as only approximate. The first is the more trustworthy. The following are a few values of the constants C and k :

Length.	Speed.	C .	k .
Less than 200 feet	About 10 knots	210	60
200 to 250 feet . .	11 "	220	60
250 to 300 " . .	12 "	240	60
300 to 400 " . .	15 "	250	65
Over 400 " . .	17 "	240	65

The effective indicator horse-power may also be calculated in terms of the area of wetted surface, by the formula:—

$$\text{Eff. I. H. P.} = \frac{W \cdot S^3}{20,000}$$

W = area of wetted surface, in square feet.

S = speed in knots per hour.

Forced Draught in Marine Boilers.

A blast of compressed air was applied in the chimney of "Resolute," with the results given in Table 299.

TABLE 299. —COMPRESSED-AIR EXHAUSTING BLAST OF THE S.S. "RESOLUTE."

Horse power of the Blowing Engine.	Horse Power of the Main Engine.	Coal consumed per Hour (Afton orquettes)	Coal per Indicator Horse Power per Hour.	Water Evaporated per Pound of Coal.
I. H. P.	I. H. P.	Pounds	Pounds.	Pounds.
0.00				
natural draught	57.5	213	3.72	10.77
0.96	88.8	289	3.26	8.82
2.00	100.5	315	3.12	8.00
3.00	106.1	321	3.04	7.82
4.20	118.8	348	2.93	7.82
5.00	119.8	374	3.12	7.58
6.00	127.9	400	3.12	7.00
7.40	135.7	420	3.10	7.00

The fuel consumed and the power were doubled, but evaporative efficiency was reduced.

From the results of trials on ships of the Navy, it appears that with open stokeholds and natural draught versus closed stokeholds and forced draught, the indicator power of the engines was increased by $52\frac{1}{2}$ per cent., and 65 per ton of boiler.

By Mr. Fothergill's system of closed ashpits and forced draught, there is an economy of 20 per cent. of coal for steaming.

With a combined forced and induced draught by compressed air into the ashpit, the speed of a steam launch was increased from 3 knots to 6 knots per hour. The quantity of water evaporated per hour was trebled.

By an induced draught caused by an exhausting fan at the base of the chimney of a marine boiler, nearly three times as much water was evaporated as by natural draught, about 6 per cent. less water was evaporated per pound of coal.

Average Weight of Steam-Engines with Boilers, Water, and all Fittings per Indicator Horse-power.

(F. C. Marshall.)

	Per I. H. P.
Merchant steamer	480 lbs.
Royal Navy	360 "
Engines specially designed for light-draught vessels	280 "
Royal Navy, Polyphemus Class	180 "
Locomotive	140 "
Turbine vessels	60 "
Ordinary Marine boilers, with water	196 "
Locomotive boilers, with water	60 "

Average Proportions and Results of Performances of Compound Engines.

(F. C. Marshall.)

	Average
Speed of piston, in feet per minute from 350 to 550	467 ft.
Working pressure of steam above the atmosphere	" 70 lbs. to 100 lbs 77.4 lbs.
Condensing surface	" 1,518 to 7,427 sq. ft.
Heating surface	" 2,379 to 11,045 "
" I. H. P. " per	" 2.77 to 6.30 " 3.92 sq. ft.
Indicator horse-power	" 560 to 2,745 I. H. P.
Coal consumption in 24 hours	" 11 to 51.9 tons.

		Average
Coal consumption per I. H. P. per hour	from $1\frac{1}{2}$ to 2 lbs.	1.83 lbs.
Heating surface per pound of coal per hour	1.65 to 3.12 sq. ft.	2.18 sq. ft.

The above proportions apply with sufficient nearness to the multiple compound practice of to-day, excepting that higher pressures are employed up to 160 lbs. per square inch in the boiler, and that the consumption of coal may, under good conditions, be reduced as low as 1.44 lbs. per I. H. P. per hour.

Horse-power of Marine Engines.

The North East Coast Institution of Engineers and Shipbuilders have framed a general rule for what they designate the Normal Indicator Horse-power on loaded trial trip of surface-condensing marine screw engines working at any boiler pressure between 50 lbs. and 250 lbs. per square inch.

$$\text{(For screw engines) N. I. H. P.} = \frac{(D^2 \sqrt{S} + 3H) \sqrt{P}}{100} \quad (7)$$

D = diameter of low pressure cylinder, in inches.

S = stroke of piston, in inches.

P = working boiler pressure, in lbs. per square inch, above the atmosphere.

H = heating surface of boilers, in square feet.

P_m = mean pressure in lbs. per square inch, reduced to low-pressure cylinder.

R = revolutions per minute.

N. I. H. P. = maximum normal indicator horse-power of loaded trial trip, of surface-condensing marine screw engines.

The conditions assumed as normal are: 1. That the steam, whatever its initial pressure, is expanded in the engines to the same pressure. 2. That the expansion is effected in the engines with the same degree of efficiency for all pressures between 50 lbs. and 250 lbs. per square inch. On this condition, for the higher pressures, engines of triple, quadruple, or more expansions, must be employed, the number of expansions depending on the initial pressure. From conditions 1 and 2, it follows that the mean pressure reduced to the low-pressure cylinder, P_m , may be assumed as proportional to the cube root of the boiler pressure, $\sqrt[3]{P}$; and that its square

loaded trial-trip value may be taken without sensible error as $5.6 \sqrt[3]{P}$. 3. That the piston speeds of engines of different lengths of stroke, are proportional to the cube roots of their respective strokes; and that the actual loaded trial-trip value of piston speed may be taken as $144 \sqrt[3]{S}$. 4. That in all cases where the engines and boilers bear to each other such proportions as to prevent condition 1 from being fulfilled, without thereby violating condition 3, the coal consumption per indicator horse-power will not be affected, but will be constant for the same boiler pressure. 5. That the boilers are constructed in accordance with the fair average practice of the present day; that if forced draught be employed, it does not exceed the average chimney draught, that the horse-power is proportional to the heating surface, H , and to the cube root of the pressure, $\sqrt[3]{P}$; and that the actual loaded trial-trip horse-power may be taken as $\frac{H \sqrt[3]{P}}{16}$. 6. That the efficiency of the engine mechanism is constant, and that the propeller is such that the engines may utilise the boiler power in the manner prescribed in conditions 3 and 4.

Deductions from the Rule.

$$I. H. P. \text{ of engines} = D^2 \sqrt[3]{P} S \quad (8)$$

$$I. H. P. \text{ of boilers} = \frac{H \sqrt[3]{P}}{16} \quad (9)$$

These values (8) and (9) are equal, and, reducing,—

$$(\text{For screw engines}) H = \frac{D^2 \sqrt[3]{S}}{3.25} \quad (10)$$

Assuming that half the sum of the powers calculated for the engines and boilers taken together, or the mean of the powers, represents the effective power of the system,—

N I. H. P. of screw engines and boilers jointly —

$$\frac{(D^2 \sqrt[3]{S} + 3 H) \sqrt[3]{P}}{100} \quad (11)$$

For paddle engines, the same formula is available, with a suitable co-efficient. Taking the piston speed at $90 \sqrt[3]{S}$ —

$$(\text{For paddle engines}) N. I. H. P. = \frac{(D^2 \sqrt[3]{S} + 5 H) \sqrt[3]{P}}{160} \quad (12)$$

$$H = \frac{D^2 \sqrt[3]{S}}{6.2} \quad (13)$$

What is known as nominal horse-power may be valued at one-sixth of the normal indicator horse-power.

In America, a standard of horse-power has come into practice, measured by 33 pounds of water evaporated per hour at a pressure of 70 lbs. per square inch above the atmosphere from 100° F. per horse-power.

PUMPING STEAM-ENGINES AND PUMPS.

The net work done, or duty effected by a pump, is equal to the product of the weight in pounds of water lifted by the height in feet through which it is raised. The efficiency of the pump is the ratio of the effective work done to the whole work expended in driving the pump. The efficiency increases generally with the height of the lift, as shown in Table 300.

TABLE 300.—EFFICIENCY, OR RATIO OF DUTY TO ENGINE
POWER OF LARGE PUMPING ENGINES.

	Head, in Feet	Efficiency, per Cent.
Cornish pumping engines	140	90.8
Rotative beam engine	20.5	86
Rotative Woolf beam	210	85 to 88
Rotative receiver beam	35	77.4
Rotative compound beam	169	83.7
Worthington pump	60.6	85
" " " " "	148.5	91.5

The duty of a pumping engine is defined as the number of pounds of water lifted one foot high, by the consumption of one lb. of coal (112 pounds). The duty may be deduced from the performance of a pumping engine expressed in pounds of coal consumed per indicator horse power, by dividing 1,980,000 by the given pounds of coal, and multiplying the quotient by 112.

Conversely, the fuel consumed per net horse-power of the pump may be calculated from the duty expressed in foot-pounds per cwt. of coal, by dividing the duty by 112, to get the duty per pound of fuel, and dividing the quotient

1,980,000. The final quotient is the quantity of coal in pounds consumed per horse-power per hour.

Or, divide 222 by the duty in millions of pounds lifted on foot per cwt. of fuel. The quotient is the quantity of coal consumed in pounds per horse-power per hour.

The duty or effective horse-power of pumping engines varies from 75 per cent. to 85 per cent. of the indicator power, for vertical direct-acting and beam rotative engines. For horizontal pumping engines, the duty horse-power is about 85 per cent. of the indicator power. The Worthington horizontal compound direct-action pumping engine, tested by Mr. J. G. Mair, realised a duty power 91½ per cent. of the indicator power, or, deducting 3½ per cent. for the aid of an auxiliary engine to work the air pump and the feed pump, a net efficiency of 88 per cent. is obtained.

The slip of large reciprocating pumps varies from 5 per cent. to 1½ per cent., or occasionally less, showing that from 95 per cent. to 98½ per cent. of the working capacity of the pump is utilised. An average of 2½ per cent. of slip may be taken. It is customary to include an allowance of 5 per cent. for slip. In rare instances there is no slip.

Of the four values, the area and stroke of the pump, and the area and stroke of the steam cylinder or of the second cylinder of a compound engine, to find the value of one, when those of the three others are known. The product of the area of the steam cylinder by the effective average pressure per square inch is equal to the product of the area of the pump barrel by the load in pounds per square inch, plus an allowance, say, of 25 per cent. to overcome frictional resistance. Whence the following rules in which the areas of the cylinder and the pump-barrel are expressed in square inches, and the pressures and loads in pounds per square inch.

1. *To find the required area of the cylinder.* Multiply the area of the air-pump by the load on the pump, and divide by the effective average pressure of steam available in the cylinder. Add 25 per cent. of the area for friction.

2. *To find the average effective steam pressure required for the cylinder.* Multiply the area of the pump by the load on the pump, and divide by the area of the cylinder. The quotient is the effective average pressure required to balance the load. Add 25 per cent. of the pressure for friction.

3. *To find the load against which the pump will deliver water.* Multiply the area of the cylinder by the effective average steam pressure, and divide by the area of the pump. From the quotient deduct 20 per cent. for friction; the remainder is the pressure or load under which water will be delivered.

4. *To find the area of the pump-barrel.* Multiply the area of the cylinder by the effective average steam pressure, and divide by the load. Deduct 20 per cent. for friction; the remainder is the area of pump-barrel required to balance the load.

In the case of compound engines, the area of the second cylinder is to be taken into the calculation; and the effective average pressure in the first cylinder is to be reduced in the ratio of the area of the second cylinder to that of the first cylinder; and, thus reduced, added to the effective average pressure in the second cylinder. The sum is to be adopted for calculation as in the case of a single cylinder.

Speed of Pistons.

The speed of steam-pistons may be from 100 feet to 200 feet per minute. The water may pass through the service-pipes at speeds of from 150 feet to 350 feet.

Six-inch three-throw pumps, raising water, performed the following duties for corresponding lifts, in parts of the indicator power :—

Water per Hour.	Lift.	Efficiency.
120 barrels	165 feet	77 per cent.
160 "	140 "	65·6 "
80 "	54 "	78·5 "
250 "	48 "	45·0 "

Centrifugal Pumps.

TABLE 301.—RAISING WATER FROM DEEP WELLS:
(Appleby.)

Quantity of Water lifted per Hour.	Lift for One Man on Crank.	Lift for One Donkey Engine.	Lift for One Horse Engine.	Lift for One Horse-Power Steam-Engine.
Gallons.	Feet.	Feet.	Feet.	Feet.
200	90	180	630	990
350	52	102	357	561
500	36	72	252	396
650	28	56	196	308
800	22	45	154	242
1000	18	36	126	198

The maximum duty of a centrifugal pump worked by a steam-engine, according to the late Mr. David Thomson, varies from 55 per cent. for smaller pumps to 70 per cent. for larger pumps. For lifts of from 15 to 20 feet, they are as economical of power as ordinary pumps; for lifts of 4 or 5 feet they are more efficient.

The height to which water would ascend in a pipe by the action of centrifugal force, would, if there were no other resistances, be that due to the velocity of the circumference of the revolving wheel, or to $\frac{v^2}{2g}$ or $\frac{v^2}{64}$.

Chain Pumps.

An endless chain, fitted with floats, circulating continuously, and drawing up an inclined plane, utilises in duty, 40 per cent. of the power applied. Lifting water through a vertical pipe, the efficiency is 65 per cent. The slip is about 17 per cent.

Hydraulic Rams.

The efficiency of the hydraulic ram is expressed by Dabuisson's formula:—

$$\frac{d'h'}{dh} = 1.42 - .28 \sqrt{\frac{h'}{h}} \quad . \quad . \quad . \quad (1)$$

d = quantity of water used, in gallons per minute.

d' = quantity of water raised, in gallons per minute.

h = head used, in feet.

h' = lift, in feet.

TABLE 302.—EFFICIENCY OF HYDRAULIC RAMS.

Ratio of Lift to Fall. Fall = 1.	Efficiency.	Ratio of Lift to Fall. Fall = 1.	Efficiency.	Ratio of Lift to Fall. Fall = 1.	Efficiency.	Ratio of Lift to Fall. Fall = 1.	Efficiency.
Ratio.	Per cent.	Ratio.	Per cent.	Ratio.	Per cent.	Ratio.	Per cent.
4	72	10	44	16	25	22	9
5	66	11	41	17	22	23	7
6	61	12	37	18	19	24	4
7	57	13	34	19	17	25	2
8	52	14	31	20	14	26	0
9	48	15	28	21	12		

The Table 302. of efficiencies was calculated by means

this formula, only five-sixths of the calculated values be taken, in order to cover contingencies.

According to Hysterweim's formula, the proper diameter of the driving-pipe, in inches, is equal to the square root of the quantity of water in gallons per minute.

Cast-Iron Water-Pipes.

The suitable thickness of cast iron water-pipes is given by the formulae,—

$$t = .25 + \frac{Hd}{9600} \quad . \quad . \quad . \quad . \quad .$$

$$t = .25 + \frac{pd}{4250} \quad . \quad . \quad . \quad . \quad .$$

t = thickness of pipe, in inches.

H = head of pressure, in feet of water.

d = inside diameter of pipe, in inches.

p = the internal pressure, in pounds per square inch.

For the usual head, 300 feet of water, the formula becomes,—

$$t = .25 + .031 d \quad . \quad . \quad . \quad . \quad .$$

For socket ends, the equivalent length of pipe, equal in weight to that of the socket, is given by the formula,—

$$\text{Equivalent length in inches} = 7 + \frac{d}{15} \quad .$$

$$\text{feet} = .6 + \frac{d}{180} \quad . \quad . \quad . \quad . \quad .$$

The additional weight for a pair of joint-flanges is equivalent to that of a lineal foot of pipe.

COAL GAS, &c.

TABLE 303. PRODUCTS OF DISTILLATION OF COAL PER TON.

	Wigan Canne.	Wigan Coal	Newcastle C.
Gas	10,900 cu. ft.	9980 cu. ft.	9700 cu. ft.
Coke	1436 pounds.	517 pounds	1540 pounds
tar	11 gallons	11 gallons	8 gallons
Ammoniacal liquor	18 "	20 "	16 "
Illuminating power of gas	24 speria candles	16 candles	15 candles
Percentage of coke	14 per cent	68 per cent.	70 per cent.

Average Yield of Bituminous Coal, by Weight.

(Newbigging.)

	Per cent.
Gas	18
Coke and breeze	68
Tar	5
Ammoniacal liquor	9
	<hr/> 100

TABLE 304.—RESULTS OF DISTILLATION OF ONE TON OF NEWCASTLE CANNEL COAL, FOR GAS AND FOR OIL.

(Gesner.)

Distilled for Gas, at from 1000° to 1200° F.		Distilled for Oil, at from 750° to 800° F.	
Gas	7450 cub. ft.	Gas	1400 cub. ft.
Tar	18½ gallons	Crude oil	68 gallons
Coke	1200 pounds	Coke	1280 pounds
<i>Products of the Tar.</i>		<i>Products of the Crude Oil.</i>	
Benzole	3 pints	Eupion	2 gallons
Coal-tar naphtha	3 gallons	Lamp Oil	22½ "
Heavy oil and naphthaline	9 "	Heavy oil and paraffin	24 "
	<hr/> 12¾ "		<hr/> 48½ "

TABLE 305.—AVERAGE COMPOSITION OF LONDON GAS, BY VOLUME.

(Dr. Letheby, 1866.)

Description of Gas.	Common Gas.	Canal Gas.
	Per cent.	Per cent.
Hydrogen	46.0	27.7
Light carburetted hydrogen	39.5	50.0
Olefiant gas	3.8	13.0
Carbonic oxide	7.5	6.8
Carbonic acid	0.7	0.1
Aqueous vapour	2.0	2.0
Nitrogen	0.5	0.4
	<hr/> 100.0	<hr/> 100.0

TABLE 306.—LONDON COAL GAS.—COMPOSITION AND CALORIFIC VALUE.
(Society of Arts, 1889)

Constituents	Proportion by Volume	Weight of One Cubic Foot of the Gas at Standard Pressure and Temperature.		Proportion by Weight.	Calorific Value per Pound of the Gas down to 100° C.	Calorific Value per Pound of Coal Gas down to 100° C.	Proportion Weight of Oxygen Required for Complete Combustion of One Pound of Coal Gas.	Weight of Oxygen Required for One Pound of Coal Gas.	Weight of Products of Combustion for One Pound of Coal Gas.
		Lbs.	Lbs.						
	Per Cent.			Per Cent.	Thermal Units.	Thermal Units.	Lbs.	Lbs.	Lbs.
C_2H_4	37.34	.447	.01689	52.8	21610	11857	4	2.112	1.188
C_2H_2	3.77	.1410	.00582	16.9	20100	3397	2	.579	.217
C_2H_6	50.44	.0359	.00282	8.9	52200	4646	8	.712	.801
H_2	3.96	.0783	.00310	9.8	4350	426	7	.056	...
O_2	3.98	.0783	.00312	9.9	...	...	...	...	...
N_2	51	.1040	.00074	1.7	...	...	...	...	...
CO_2	100.00	...	.03159	100.0	...	19826	...	3.459	2.206
									2.137

Calorific value of one cubic foot = $10896 \times .0316 = 526$ thermal units.

Weight of Coal.

	Per Cubic Foot, Solid.	Per Cubic Foot, Heaped.	Cubic Feet in One Ton, Heaped.
Anthracite	85.4 lbs.	58.3 lbs.	38.4 cubic feet
Bituminous	78.3 "	49.8 "	45.3 "
Cannel	76.8 "	48.3 "	46.4 "

TABLE 307.—CALORIFIC VALUE OF COAL GAS.

(T. L. Miller.)

Place of Manufacture.	Heating Power per Cubic Foot.
	Heat Units.
Glasgow	813
Liverpool	770
Kilmarnock	680
Manchester	654
Birmingham	639
London	624
Hoboken	617
Berlin	549

Weight of Lime.

1 bushel of quicklime weighs about	70 lbs.
1 cubic foot " " "	54 "
1 cubic yard " " "	1460 "
1 ton " measures about	32 bushels.

Area of pipe surface required for condensation of gas—
10 square feet per 1000 cubic feet of maximum production per
day of 24 hours (*lowhugging*).

Illuminating Power of Gas.

The standard for comparison of gases for illuminating power is the sperm candle, weighing six to the pound, each burning off at the rate of 120 grains of sperm per hour. The gas for comparison is burned at the rate of 5 cubic feet per hour.

The gas supplied in London averages more than 16 candles for illuminating power. In fact, the larger companies are required, by Acts of Parliament, to supply gas of such a quality, that when burned through the Government standard Argand burner at the rate of 5 cubic feet per hour, it shall be capable of giving a light equal to that of 16 sperm candles, of six to the pound, when each candle is burning.

the rate of 120 grains of material per hour. This is called common gas. The London Companies, and most provincial companies are required to maintain in all their street mains pressure equal to a column of water 1 inch in height, between sunset and midnight, and a pressure of $\frac{9}{10}$ inch between midnight and sunset.

Main Pipes.

Main pipes should be tested to 150 feet of water pressure. Cast iron pipes below 3 inches bore are made in lengths of 6 feet, from 3 inches to 11 inches, 9 feet long, 12 inches and upwards, 8 feet or 9 feet long.

The weight of cast-iron pipes is given by the formula, -

$$W = 2.45 (D^2 - d^2) \quad \dots \quad (C)$$

D = diameter, outside, in inches.

d = diameter inside, in inches.

W = weight in pounds per lineal foot.

The weight of a socket is equal to $\frac{8}{10}$ ths of that of a lineal foot of the pipe.

TABLE 308.—THICKNESS OF CAST-IRON GAS MAIN PIPE.

Diameters.	Thick- ness.	Diameters.	Thick- ness.	Diameters.	Thick- ness.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1, 1½, 2	$\frac{5}{8}$	12, 13, 14, 15	$\frac{3}{8}$	30	1
2½, 3, 4	$\frac{3}{4}$	16, 17, 18	$\frac{11}{16}$	36	1½
5, 6	10	19, 20, 21	$\frac{3}{4}$	42	1½
7, 8, 9	$\frac{3}{4}$	22, 23	$\frac{13}{16}$	48	1½
10, 11	$\frac{3}{4}$	24	$\frac{7}{8}$		

TABLE 309.—THICKNESS AND WEIGHT OF WROUGHT-IRON GAS PIPES.

Diameter.	Thickness.	Weight per Lineal Foot.
Inches.	Inches.	Pounds.
3, 3½	$\frac{5}{16}$ full	6, 7
4, 5, 6	$\frac{3}{16}$	9, 10½, 13
7, 8, 9	$\frac{1}{4}$ bare	16, 20, 24½
10, 12	$\frac{1}{4}$	28, 33
14, 16	$\frac{3}{16}$	48, 56

TABLE 310. SMALL GAS-TUBES.

Diameter Inside.	Light.		Heavy.	
	Weight per Yard.	Length of Bundles.	Weight per Yard.	Length of Bundles.
Inches.	Lbs. Oz.	Yards	Lbs. Oz.	Yards.
$\frac{1}{4}$	0 11 $\frac{1}{2}$	80	0 15	67
$\frac{3}{8}$	1 2	60	1 6 $\frac{1}{2}$	46
$\frac{1}{2}$	2 0	32	2 10	16
$\frac{3}{4}$	2 4	25	3 0	20
$\frac{3}{4}$	3 3	23	3 12	19
1	4 8	26	6 0	20
1 $\frac{1}{4}$	8 0	16	10 0	12
1 $\frac{1}{2}$	12 0	10	14 0	9
2	18 1	5	21 0	5

TABLE 311. SMALL BRASS TUBES.

Diameter Outside.	Weight per Foot.	Diameter Outside.	Weight per Foot.
Inches.	Pounds or Ounces.	Inches.	Pounds or Ounces.
$\frac{1}{8}$	08 or 1 28	$\frac{1}{8}$	50 or 8 00
$\frac{5}{16}$	15 " 2 40	1	59 " 9 44
$\frac{3}{8}$	19 " 3 04	1 $\frac{1}{4}$	81 " 12 96
$\frac{7}{16}$	21 " 3 36	1 $\frac{1}{2}$	1 00 " 16 00
$\frac{1}{2}$	25 " 4 00	1 $\frac{3}{4}$	1 12 " 17 92
$\frac{9}{16}$	31 " 4 96	2	1 25 " 20 00
$\frac{5}{8}$	37 " 5 92	2 $\frac{1}{2}$	1 50 " 24 00
$\frac{3}{4}$	43 " 6 88	3	1 87 " 24 92

Flow of Gas through Pipes.

Dr. Pole's formula for the volume of gas delivered through large pipes is as follows, —

$$Q = 1350 d^2 \sqrt{\frac{hl}{s}} \quad (2)$$

Conversely, the diameter of pipes required for a given rate of delivery, is, —

$$d = \sqrt[3]{\frac{Q \sqrt{s}}{1350 \sqrt{hl}}} \quad (3)$$

Q — quantity of gas delivered, in cubic feet per hour.

l — length of pipe, in yards.

d — diameter of pipe, in inches.

h — pressure in inches of water.

s — specific gravity of gas = .40 ; that of air being 1.

For any other specific gravity, multiply the value of Q given by formula (2), by $\cdot 6325$ (or $\sqrt{0.40}$), and divide the product by $\sqrt{\text{specific gravity}}$.

The discharge for small pipes is less than the calculated quantity. The value of d by formula (3) is to be augmented one-third for lead service pipes; and one-half for wrought-iron service pipes.

Dowson Gas.

The Dowson gas is a cheap gas, generated by passing a mixture of superheated steam and air through a mass of red-hot carbonaceous fuel—anthracite by preference. The composition of the gas, generated with Garnant anthracite, analysed by Professor William Foster, is as follows,

	Volume per cent.
Hydrogen	18.73
Marsh gas . . . . .	.31
Olefiant gas . . . . .	.31
Carbonic oxide	25.07
Carbonic acid	6.57
Oxygen . . . . .	.03
Nitrogen	48.98
	<hr/> 100.00

The calorific power of Dowson gas is about one-fourth that of London gas. The anthracite fuel consumed per 100 cubic feet is 13.2 pounds. Tested by D. K. Clark, in working an Otto gas engine developing 4.41 indicator horse-power and 3.25 break horse-power, at a speed of 156 revolutions per minute, the following results were yielded.—

Gas consumed per indicator horse-power	110.34 cubic feet.
" " break	149.30
Fuel " " indicator	1.45 lbs.
" " break	1.07 "

The cost of Dowson gas is 30 per cent. less than that of coal-gas at 3s. per 1000 cubic feet. Whilst coal-gas of average composition requires chemically 5.3 volumes of air for combustion, each volume of Dowson gas requires only 1.1 volume of air.

More recently, Mr. Dowson has produced his gas from ordinary gas-coke. From the results of thirteen Otto engines using Dowson gas, indicating from 150 to 16 horse-power, it appears that from 1.5 pounds to 1.2 pounds of fuel was consumed per indicator horse-power per hour.

TABLE 312.—OIL GAS, FROM BLUE PARAFFIN OIL.
(Macadam.)

Items.	Pullich's Apparatus.			Keth's Apparatus.		
	1	2	Mean	1	2	Mean
Specific gravity of oil	878	878	878	874	878	876
Flashing point	296°	294	295	292°	286°	289°
Firing point	356°	352°	354°	348°	346°	347°
Gas per gallon, cubic feet	90.7	103.4	97	85	84.8	84.0
Illuminating power	62.5	59.1	60.8	63.2	59.5	61.4
Volume of oil in gallons, flowing in to each retort, per hour	1.4	1.18	1.29	2.3	1.9	1.8
Gas per retort, per hour, cubic feet	126.8	122.5	124.6	197.5	111.9	154.7
Heavy hydrocarbons, per cent.	89.2	37.1	38.2	31.9	38.2	31.0
Gas per ton, cubic feet	23,196	26,356	24,742	21,779	21,671	21,721

TABLE 313. PRODUCER GAS COMPOSITION, BY WEIGHT

Elementary Gases.	H. Hydro- gen.	CO Carbonic Oxide.	CO ₂ Carbonic Acid.	CH ₄ Marsh Gas.	C ₂ H ₂ Olefant Gas.	N.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Siemens Producer	60	24.92	0.35	89	2.73	64.50
"	65	24.97	8.71	1.45		13.22
Wilson Producer	90	20.58	4.91	91		11.70
"	1.11	20.33	8.20	1.43		2.84

Gas Engines.

The Crossley gas engine, horizontal, is constructed with a single cylinder, of nominal powers of from $\frac{1}{2}$ H.P. to 30 H.P., indicating from 2 H.P. to 85 H.P.; and with double cylinders of from 4 H.P. nominal to 30 H.P. indicating from 16 H.P. to 175 H.P. The overall dimensions of the engine only, single cylinder, vary from 6 feet by 3 feet 7 inches, to 12 feet by 8 feet 2 inches. The speed of the engines is at the rate of 160 revolutions per minute, except for the $\frac{1}{2}$ H.P. and the 1 H.P. engines, which make 180 per minute.

The 12 H.P. engine has developed 28 indicator H.P., and 28 H.P. at the break, or 82 per cent. of the indicator power, consuming 20 cubic feet of gas per indicator horse power per hour, or 21.3 cubic feet per break horse-power. In a 4 H.P. engine, 23.3 cubic feet was consumed per break horse-power.

The following Table 314, gives some results of trials of Crossley gas engine.* The cylinder was $9\frac{1}{2}$ inches in diameter with a stroke of 18 inches, single-acting. The gas used was of the composition shown in Table 306.

TABLE 314. CROSSLEY GAS ENGINE RESULTS OF TRIALS

Trial	A	B	C
Power	Full	Half	Empty
Revolutions per minute	160.1	158.8	161.6
Explosions per minute	78.4	41.1	19.2
Mean initial pressure Lbs.	196.9	196.2	48.0
Mean effective pressure "	67.9	73.4	66.7
Indicator horse-power H.P.	17.12	9.73	2.19
Break horse-power "	14.74	7.41	..
Mechanical efficiency Per cent.	80.1	76.2	..
Gas per hour, main Cub. ft.	351.8	202.6	49.0
" " for ignition "	3.7	3.2	..
" " total "	355.3	205.8	..
Gas per indicator H.P. per hour, main, Cub. ft. }	20.55	20.8	22.2
" " " " " total ..	20.76	21.2	..
Gas per break H.P. per hour, main ..	23.87	27.34	..
" " " " " total ..	24.10	27.77	..
Water for cooling per hour Lbs.	713	480	..
Rise of temperature Fahr.	128° 0	102° 3	..
Power to drive engine only H.P.	2.38	2.31	2.19
Mean pressure during working stroke, equivalent to work done in pumping strokes Lbs.	2.19	..	..
Corresponding indicator H.P.	5.5	..	..

The distribution of the heat of combustion of the gas working the Crossley engine, was as follows, -

Trial.	A	B.	C.
	Per cent.	Per cent.	Per cent.
Heat turned into work	22.1	20.9	19.4
Heat rejected in jacket water	43.2	41.1	..
Heat rejected in exhaust	35.5	38.0	..
	100.8	100.0	..

* See Report of the Judges on Trials of Motors for Electric Light for the Society of Arts.

TABLE 315. RESULTS OF TRIALS OF GAS ENGINES. (T. L. Miller.)

Type of Engine.	Tested by	Indicator H. P. Power	Break Horse Power	Gases per L. H. P.	Cub. Feet.	G. per B. H. P.	Heat Converted into Work	Revolutions per Minute	Speed of Piston per Minute.
Otto	Adams	3.42	2.87	30.9	39.4	14.46	14.46	160.3	320.6
"	"	22.56	18.31	28.6	29.1	17.5	17.5	158.7	423.2
"	"	33.6	27.75	25.04	30.3	16.15	16.15	151.37	429.7
Clerk	Society of Arts	17.12	14.75	20.55	23.87	21.2	21.2	160.1	480.3
"	Garrett	3.62	2.70	29.8	40	10.5	10.5	212	308
"	"	9.05	7.23	24.3	30.42	12.9	12.9	146	292
"	"	27.46	23.21	20.89	24.12	15.5	15.5	132	449
Beck	Kennedy	7.35	5.71	21.18	27.27	20.7	20.7	212	530
"	"	6.12	4.84	20.67	26.14	21.1	21.1	168.9	422.8
Griffin	Jameson	17.28	13.6	19.27	24.48	20.8	20.8	183	427
"	Kennedy	17.46	14.94	18.92	24.58	24.2	24.2	223.8	522
"	Society of Arts	15.47	12.51	22.64	28	19.2	19.2	138.1	423.5
"	Witz	"	6.70	...	21.55	19.4	19.4	150	420
Simplex	"	"	8.67	...	20.12	20.9	20.9	160	420
"	R. H. Smith	5.51	4.807	20.79	23.97	19.2	19.2	...	...
Forward	Jameson	10.94	8.81	18.9	21.5	...	...	...	...
Ajax	Miller	11.49	8.72	18.4	24.74	19.3	19.3	...	...
Farwell	Unwin	5.55	4.884	19.78	22.31	21.9	21.9	...	...
Atkinson	Society of Arts	11.1	9.48	19.22	22.61	22.8	22.8	...	...
"	Bird	40	tar or creosote	tar or creosote	...	31.4	31.4	...	...
Atkinson	"	5.17	tar or creosote	tar or creosote	...	14.4	14.4	...	...

A Griffin gas engine, double-acting, was similarly tested. The cylinder was 9.02 inches in diameter, with a stroke of 14 inches. Three trials were made at full power, half power, and empty.

Trial.	A. Per cent.	B. Per cent.	C. Per cent.
Heat turned into work	21.1	19.4	17.5
Heat rejected in jacket water	35.2	32.5	...
Heat rejected in exhaust	39.8	...	...
Unaccounted for, including heat rejected in blank charge of air . }	3.9	48.1	...

Oil Engines.

Oil engines are in considerable employment as oil motors. In the Priestman oil engine, mineral oil or petroleum is used, having a specific gravity of .800 or upwards, with a flashing point from 75° to 150°. The oil is mixed with air under pressure, is drawn into the cylinder, and ignited by an electric spark from a small ordinary battery. The consumption of oil varies from about 1.25 pints or 1½ pounds per break horse-power per hour for the larger engines, to 1.60 pints or 1.60 pounds for the smaller engines. An engine having an 8½-inch cylinder, with a 12-inch stroke, made 180 revolutions per minute, and developed 4.60 break horse-power, with a consumption of 1.20 pints or 1.20 pounds of oil per horse-power per hour. In a half-power trial, 2.36 break horse-power was developed on a consumption of 1.20 pints or 1.20 pounds of oil.

The Hargreaves motor is designed for burning coal-tar or creosote as fuel. It consists of an air-compressing pump and motor cylinder, to the latter of which a regenerator is adapted, which absorbs a portion of the heat of the exhaust gases, and yields it up to the incoming charge. The compressed-air is delivered through the regenerator into the motor cylinder, where it meets a jet of coal-tar or creosote, and, being heated to redness, ignites the fuel. Results of trials are given in Table 315 (p. 567), by Mr. Miller, who gives results of other trials, in one of which, a net power of 40 indicator H.P. was generated, by the consumption of .512 pounds of coal-tar per indicator horse-power per hour. In another trial, with a smaller engine, for a net indicator power of 5.17 H.P., 1.2 pounds of creosote were consumed per indicator horse-power per hour.

AIR IN MOTION.

DR. HUTTON'S statement of the law of resistance of air to bodies in motion, has been corroborated. It is that in the case of slow motion, the resistance is nearly as the square of the velocity; gradually increasing more and more above that proportion as the velocity increases.

TABLE 316.—RESISTANCE OF AIR TO FLAT VANES, SQUARE AND ROUND.
(Fairweather.)

Size.	Area.	Speed in Feet per Second.					
		5	10	15	20	25	30
Inches.	Sq. Ft.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
SQUARE.							
7.41	.38	.55	1.4	3.25	5.7	9.4	14.0
12.9	1.155	1.30	5.5	13.60	...	...	...
15.58	2.40	3.25	15.0	...	...	...	...
CIRCLE.							
7.24	.286	.30	1.15	2.6	4.6	7.4	10.9
12.65	.875	.85	3.85	9.1	16.4	...	...
18.36	1.840	2.40	10.00	...	...	...	...

Empirical formula for the velocity and pressure of high winds :—

$$P = \frac{V^2}{10} \quad (1)$$

$$V = \sqrt{10P} \quad (2)$$

V = maximum run of wind in any one hour.

P = maximum pressure, in pounds per square foot, at any time during the storm, to which V refers.

The formula (1) represents very fairly the greatest pressure as deduced from the mean velocity for an hour. The following are the greatest recorded pressures of wind per square foot, at various places :—

	Per Square Foot		Per Square Foot
Aberdeen	41 Lbs.	Liverpool	30
Armagh	27 ..	London	20.2
Birmingham . . .	27 ..	Valentia	6.6
Edinburgh	35 ..	Yarmouth	42.2
Falmouth	53.7 ..	Brussels	22
Glasgow	47 ..	Paris	17
Greenwich	42 ..	Bombay	38
Halifax	30.2 .	Calcutta	40
Holyhead	64 .	Madras	34
Kew	27 ..		

The Committee appointed to investigate the question recommended that a maximum wind-pressure of 56 lbs. per square foot, should be employed in calculations for railways, bridges and viaducts.

Flow of Air in pipes.

Mr. Hawksley's formulæ for the flow of air through pipes under small differences of pressure, are as follows :—

$$v = 36.4 \sqrt{\frac{h d}{l}}$$

$$h = \frac{l v^2}{150,800 a}$$

v = velocity in feet per second.

h = head or drag in inches of water.

d = diameter of pipe, in feet.

l = length of pipe, or other passage, in feet.

c = perimeter, in feet.

a = sectional area of pipe, or other passage, in square feet.

Q = Quantity of air discharged, in cubic feet per second.

H = effective horse power required for net work of discharge of air.

Flow of air through passages of any form of section, as shafts, air-ways, and tunnels

$$v = 79.6 \sqrt{\frac{a h}{c l}}$$

$$h = \frac{v^2 c l}{633,900 a}$$

Quantity of Air delivered per Second

$$\text{From a pipe, } Q = 311 \sqrt{\frac{h d^5}{l}} \quad (7)$$

$$\text{From a passage of any section, } Q = 796 \sqrt{\frac{u^3 h}{l}} \quad (8)$$

The density of dry air at 62° F., is taken at $\frac{1}{812}$ part of the density of water at 62.4 pounds per cubic foot: and 1 inch of water as equivalent to a pressure of 5.20 lbs. per square foot.

Effective Horse-power for net work of discharge of air.

$$\text{From a pipe, } H = \frac{r d^5 h}{3.3} \quad (9)$$

$$\text{" } H = \frac{r^3 d^3 l}{21,200,000} \quad (10)$$

$$\text{from a passage of any section, } H = \frac{r a h}{106} = \frac{Q h}{106} \quad (11)$$

$$\text{" } H = \frac{r^3 a l}{67,000,000} \quad (12)$$

Natural Flow of Air in Shafts of Mines.

Mr. Hawksley's formula for the velocity of air in the up-cast shaft of a mine, due to difference of temperature is:—

$$v = 96 \sqrt{\frac{(T + 148) D a}{m l + 568 a}} \quad (13)$$

T = temperature of air in up-cast shaft (Fahr.).

t = temperature of air in down-cast shaft.

D = depth of shaft in feet.

m = periphery of air course, in feet.

a = section of air course in square feet.

l = length traversed by the current, in feet.

v = velocity of current, in feet per second.

Fans — Ventilators.

The following Table 317, of the most suitable dimensions of fans, is based on the results of Mr. Black's experiments. The case is of the form of an arithmetical spiral, widening the clear space between the case and the revolving blades, circumferentially, from the origin to the opening for discharge.

TABLE 317.—DIMENSIONS OF FANS.

Pressure from 8 ounces to 6 ounces per square inch ; or
5·2 inches to 10·4 inches of water.

Dia- meter of Fan.	Vanee.		Dia- meter of Inlet Open- ings.	Dia- meter of Fan.	Vanee.		Dia- meter of Inlet Open- ings.
	Width.	Length.			Width.	Length.	
Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
3 0	0 9	0 9	1 6	4 6	1 1½	1 1½	2 3
3 6	0 10½	0 10½	1 9	5 0	1 3	1 3	2 6
4 0	1 0	1 0	2 0	6 0	1 6	1 6	3 0

Pressure, from 6 ounces to 9 ounces per square inch, and
upwards, or 10·4 inches to 15·6 inches of water.

3 0	0 7	1 0	1 0	4 6	0 10½	1 4½	1 9
3 6	0 8½	1 1½	1 3	5 0	1 0	1 6	2 0
4 0	0 9½	1 3½	1 6	6 0	1 2	1 10	2 4

Guibal's fan, for mine ventilation, has blades which are straight, except at the outer ends, which curve forwards. The blades are fixed at a back inclination,—usually 45°—to the radius. The wheel is closely surrounded, for about two-thirds of the circumference, by a casing of brickwork. For the remaining third, the casing gradually opens out into the discharge vent, which expands upwards as an inverted frustum of a cone. A Guibal fan working at Staveley colliery, is 30 feet in diameter, 10 feet wide, it makes 60 revolutions per minute, with the following results of performance :—

Speed in Turns per Minute.	Draft in Inches of Water.	Volume of Air Discharged per Minute.	Efficiency, in parts of the Gross Indicator Power of the Engine.
Turns.	Inches.	Cu. Ft.	Per cent.
32	·70	100	40·4
51	1·70	100	43·1
64	2·77	100	53·3
68	3·10	100	

COMPRESSED AIR.

Compressed or Expanded Isothermally.

Air when compressed or expanded under a uniform temperature, or isothermally, follows the hyperbolic law, according to which the pressure varies inversely as the volume.

The total net work for one stroke of the compressor of dry atmospheric air, isothermally, is found by the formula

$$W = P (V + v) \text{ hyp. log. } \frac{V' + v}{V + v} (P' - P) r \quad (1)$$

The total net work of dry air for one stroke of a compressed air engine isothermally expanded in the cylinder down to atmospheric pressure, is given by formula

$$W = P (V + v) \text{ hyp. log. } \frac{V' + v}{V + v} (P - P') r \quad (2)$$

The formulas (1) and (2) are identical in construction.

In cases where the back pressure P'' is less than P' , the terminal positive pressure, the total net work is given by formula

$$W = P (V + v) \text{ hyp. log. } \frac{V' + v}{V + v} P'' V' + P V \quad (3)$$

P = total pressure of air, in pounds per square foot.

V = volume of air, in cubic feet.

v = volume of clearance at each end of cylinder, in cubic feet.

W = work done, in foot pounds.

In practice, the temperature is not uniform but rises with compression, and falls with expansion, requiring more work for compression, and less work by expansion than are provided in the above formulas. But these differences are minimised by the application of cooling agents, as cold water surrounding the working cylinder.

In compressing dry air at 62° F. in a non-conducting vessel, adiabatically, to two atmospheres of pressure, the temperature is raised to 178° F.; and the fall to 62°, in a reservoir, involves a loss of 116°, which is a loss of 18 per cent. of the maximum absolute temperature, or 18 per cent. of efficiency for work.

TABLE 318.—PRESSURE AND VOLUME OF COMPRESSED AIR.
(Adapted from Mr. Stone's Table.)

Lbs. per Sq. In.	Inches of Mercury.	Feet of Water.	Volume of Air after Compression to Initial Volume.		Temperature of Air after Compression.	Rate of Compression Isothermally.	Isothermally.
			Isothermally.	Adiabatically.			
1	2.041	2.04	0.939	0.754	70.04	1.0089	0.939
2	4.082	4.08	0.880	0.613	79.64	1.1361	0.880
3	6.123	6.12	0.83	0.530	88.84	1.2041	0.83
4	8.164	8.16	0.786	0.464	97.68	1.270	0.786
5	10.205	10.20	0.746	0.412	106.18	1.3404	0.746
6	12.246	12.24	0.710	0.374	114.39	1.4084	0.710
7	14.287	14.28	0.677	0.340	122.32	1.4742	0.677
8	16.328	16.32	0.648	0.313	130.00	1.5442	0.648
9	18.369	18.36	0.620	0.293	137.43	1.6122	0.620
10	20.410	20.41	0.595	0.270	144.65	1.6803	0.595
11	22.451	22.45	0.572	0.253	151.66	1.7453	0.572
12	24.492	24.49	0.551	0.239	158.48	1.8164	0.551
13	26.533	26.53	0.531	0.228	165.13	1.8844	0.531
14	28.574	28.57	0.512	0.219	171.60	1.9521	0.512
15	30.615	30.61	0.495	0.207	177.90	2.0204	0.495
16	32.656	32.65	0.479	0.198	184.09	2.0884	0.479
17	34.697	34.69	0.464	0.190	190.11	2.1565	0.464
18	36.738	36.73	0.450	0.183	196.00	2.2245	0.450
19	38.779	38.77	0.436	0.175	201.77	2.2925	0.436
20	40.820	40.82	0.424	0.168	207.42	2.3605	0.424
21	42.861	42.86	0.412	0.163	212.95	2.4286	0.412
22	44.902	44.90	0.401	0.157	218.37	2.4966	0.401
23	46.943	46.94	0.390	0.152	223.69	2.5646	0.390
24	48.984	48.98	0.380	0.147	228.91	2.6325	0.380
25	51.025	51.02	0.370	0.143	234.03	2.7004	0.370
26	53.066	53.06	0.361	0.139	239.07	2.7684	0.361
27	55.107	55.10	0.353	0.135	244.02	2.8365	0.353
28	57.148	57.14	0.344	0.131	248.88	2.9045	0.344
29	59.189	59.18	0.336	0.128	253.69	2.9725	0.336
30	61.230	61.23	0.329	0.124	258.47	3.0405	0.329
31	63.271	63.27	0.322	0.121	263.20	3.1085	0.322
32	65.312	65.31	0.315	0.118	267.89	3.1765	0.315
33	67.353	67.35	0.308	0.115	272.54	3.2445	0.308
34	69.394	69.39	0.302	0.112	277.15	3.3125	0.302
35	71.435	71.43	0.296	0.109	281.72	3.3805	0.296
36	73.476	73.47	0.290	0.107	286.25	3.4485	0.290
37	75.517	75.51	0.284	0.104	290.75	3.5165	0.284
38	77.558	77.55	0.279	0.102	295.20	3.5845	0.279
39	79.599	79.59	0.274	0.100	299.61	3.6525	0.274
40	81.640	81.64	0.269	0.098	303.98	3.7205	0.269
41	83.681	83.68	0.264	0.096	308.31	3.7885	0.264
42	85.722	85.72	0.260	0.094	312.60	3.8565	0.260
43	87.763	87.76	0.255	0.092	316.85	3.9245	0.255
44	89.804	89.80	0.250	0.090	321.06	3.9925	0.250
45	91.845	91.84	0.246	0.088	325.23	4.0605	0.246
46	93.886	93.88	0.242	0.086	329.37	4.1285	0.242
47	95.927	95.92	0.238	0.084	333.48	4.1965	0.238
48	97.968	97.96	0.234	0.082	337.55	4.2645	0.234
49	100.009	100.00	0.231	0.080	341.59	4.3325	0.231
50	102.050	102.05	0.227	0.078	345.60	4.4005	0.227

The following table shows the corresponding loss of efficiency for several pressures.—

TABLE 319.—LOSS OF EFFICIENCY OF COMPRESSED AIR.

Pressure.	Final Temperature for Compression.	Reduced Efficiency, Initial Temperature for Work, 62° F.	Loss of Efficiency.
Atmospheres.	Fahr.	Per cent.	Per cent.
2	178	82	18
3	258	73	27
4	321	67	33
5	373	63	37
10	559	51	49

Taking the efficiency of the compressor, and also that of the power-engine, at 80 per cent, the resultant efficiency of the combined compressor and engine, working to 10 atmospheres is $\left(\frac{80 \times 80}{100} \times 51 \right)$ 33 per cent. Working to two atmospheres, the resultant efficiency is 52 per cent. In general practice, the resultant efficiency rarely exceeds 30 per cent.

Table 318 shows the relation of pressure, volume, and temperature, with the load against a compressing piston.

Table 320 shows the net horse power required for compressing atmospheric air, under pressures of from 2 to 20 atmospheres, calculated by means of formula (1), on the assumption that the temperature is maintained uniformly at 62° F.

The same table shows reversely, the horse-power developed by compressed air introduced into the cylinder at the various pressures; on the assumption that the temperature is uniformly 62° F., and that the air is expanded down to atmospheric pressure at the end of the stroke. But, when the air is exhausted, at a pressure higher than that of the atmosphere, the difference of the initial work PV and the work of back pressure, $P''V'$, is to be added to the work as calculated by formula (3).

Flow of Compressed Air through Pipes.

The head, or difference of the pressures at the beginning and end of a long pipe, through which compressed air is forced, may be taken to vary as the length of the pipe, as the square of the velocity, and inversely as the diameter. According to some authorities, it varies also with the density of the air; according to others it does not so vary. In Table 321 are given the results of observations made on the flow of compressed air in pipes at the St. Gothard tunnel.

TABLE 320. -NET POWER REQUIRED TO COMPRESS AIR AT THE UNIFORM TEMPERATURE 62° F.

Atmospheres of Pressure, and Ratio of Expansion. 1 Atmosphere = 1	Pressure per Square Inch (approximate).	Horse Power per cubic Foot of Compressed Air per Minute.	Volume of Compressed Air per Minute per Horse Power, at 62° F.	Equivalent Volume of Free Air, at 62° F.
Hyperbolic Logarithm of Ratio of Expansion.	Lbs.	H. P.	Cubic Feet.	Cubic Feet.
2	0.31	30	0.883	11.25
3	1.0986	45	2.134	4.73
4	1.3863	60	3.506	2.88
5	1.6094	75	5.16	1.94
6	1.7918	90	6.90	1.450
7	1.9459	105	8.74	1.115
8	2.0794	120	1.067	0.938
9	2.1972	135	1.268	0.788
10	2.3026	150	1.477	0.667
11	2.3979	165	1.692	0.591
12	2.4849	180	1.913	0.523
13	2.5649	195	2.139	0.468
14	2.6391	210	2.369	0.422
15	2.7084	225	2.606	0.384
16	2.7726	240	2.845	0.352
17	2.8332	255	3.089	0.324
18	2.8904	270	3.336	0.300
19	2.9444	285	3.587	0.279
20	2.9957	300	3.843	0.260

At the Mont Cenis tunnel, compressed air of 3.70 atmospheres of pressure was reduced to 5.50 atmospheres, or by $3\frac{1}{2}$ per cent. of the head, in a $7\frac{1}{2}$ inch cast-iron pipe 1775 yards in length, comprising 100 ft. of frictional resistance, while 61 cubic feet of compressed air was delivered per minute. In a length of 6 666 yards of pipe, the loss was 5 per cent. of the initial pressure.

The Table 322 of loss of pressure by friction in pipes has been issued by the Rand Drill Company. The calculated quantities are those for straight pipes. To make ample allowance for heads, elbows, and tees, one size of pipe larger than the tabular size may be taken.

TABLE 321.—LOSS OF PRESSURE IN COMPRESSED-AIR PIPE MAIN, AT ST. GOTHARD TUNNEL.
(E. Stockalper.)

Expt. Number.	Air Main. Diameter Length	Volume per Second of			Mean Density of Com- pressed Air. Water 1)	Weight of Air flow- ing per Second	Mean Velocity in Feet per Second	Mean Tempe- rature in Main	Observed Pressures.			
		Free Air or Equivalent Volume at Atmos- pheric Pressure and 32° F.	Cubic Feet	Cub. Ft. per Second					Pres- sure at Begin- ning of Pipe	Atmos.	Pres- sure at End of Pipe.	Loss of Pressure.
No.	Inches	Feet.			Density	Lbs.	Feet.	Fahr.	Atmos.	Atmos.		Per Cent.
1	7.87	15,092	6.534	3065.0	0.0650	2.689	19.32	70	5.60	5.24	0.36	6.4
	7.91	1,712.6	7.068	0.0603	2.669	37.14	80	80	5.24	5.00	0.24	4.6
2	7.87	15,092	5.509	0.0514	1.776	10.30	70	70	4.35	4.13	0.22	5.1
	7.91	1,712.6	5.863	0.0482	1.776	...	80	80	4.13	...	...	...
3	7.87	15,042	5.262	0.0449	1.483	15.58	70	70	3.84	3.65	0.19	5.0
	7.91	1,712.6	5.604	0.0423	1.483	29.34	80	80	3.65	3.54	0.11	3.0

REFRIGERATING MACHINERY.

For the cooling of brine and other liquids by the alternate compression and expansion of air, Mr David Thomson gives the following formulæ, in which the machine is supposed to be perfect —

$$P = 772 C \times \frac{T}{T'} \cdot \frac{T}{T'} \quad (1)$$

$$C = \frac{P}{772} \times \frac{T}{T - T'} \quad (2)$$

P—power required to do the cooling work C, in foot-pounds.

C—cooling work done, in thermal units.

T= Absolute maximum temperature Fahrt., of the air in the hot or compression end of the cooling machine.

T'—absolute minimum temperature, Fahrt., of the air in the cold or expansion end of the machine.

These formulæ indicate that the most economical results, as regards consumption of power, are obtained when the machine is worked within a small range of temperature, as in breweries, where the temperature of water is frequently to be lowered only 10° F.

These formulæ are applicable to all cooling machines, whether they operate by means of air, ether, ammonia, or any other fluid. In the ammonia machine, or other machine working on the same principle, in which no mechanical power is applied, the value of P, it is understood, is the heat theoretically required, at the rate of 1 heat-unit for 772 foot-pounds of power: and the formula (1) becomes,—

$$(\text{Ammonia}) \text{ Heat required to do the work } C = C \frac{T}{T'} \cdot \frac{T}{T'} \quad (3)$$

The ammonia machine has, theoretically, a great economical superiority, as heat is so much less expensive than its equivalent of mechanical power.

The nature of the vapour employed affects the size of the machine; the relative capacity of cylinder required being—

Ammonia 1	Methyl ether 1.8
Carbonic acid 0.16	Sulphurous acid 2.6
Methyl chloride 1.8	Ether 15.1

HOT-AIR ENGINES.

In Rider's Hot-air Engine, called a compression engine, two single-acting cylinders are placed vertically, side by side, connected at the upper part by a regenerator composed of thin plates. One of these is the working or hot cylinder, under which a fire is maintained; the other is the air-pump, or cold cylinder, surrounded by water to cool the air which is drawn into it, and which is pumped into the hot cylinder. The plungers of the cylinders are worked by cranks forming an angle of 95° , on a shaft overhead. The 1-horse-power engine has $6\frac{1}{2}$ -inch plungers, with strokes of $9\frac{1}{2}$ inches hot, and 8.6 inches cold. At a speed of 120 turns per minute, the effective mean pressure in the hot cylinder was 16.8 lbs. per square inch, and in the cold cylinder 7.15 lbs.; leaving 10.33 lbs. net effective pressure on the hot plunger, making 1.076 horse-power. It is stated that the coal consumed was at the rate of from 2 lbs. to 3 lbs. per net indicator horse-power.

In Benier's Hot-Air Engine, the air is heated within the working cylinder by means of a furnace within the cylinder. All the heat of combustion is directly utilised; the valves are only traversed by cold air, and the heated air acts directly as it expands on the piston. It is stated that the consumption of coke is at the rate of 3.3 pounds per horse-power per hour for motors of 4 horse-power; and 4 pounds for motors of 2 horse-power.

WATER POWER.**Flow of Water.**

The flow of water by the action of gravity, if there be no deduction from the force, is according to the formula, —

$$v = 8\sqrt{h} \quad (1)$$

v = velocity in feet per second.

h = height of fall in feet.

The velocity of water discharged through the side of a vessel is variously affected by the form of the orifice.

parts of the theoretical velocity v , as above, the velocity varies thus —

	Per cent
With internal tube	50
Thin plate only	62
Nozzle 2 diameters in length	82
Converging cone, length $2\frac{1}{2}$ diameters	95
Vena contracta, length $\frac{1}{2}$ diameter of orifice	160
Smallest diameter .785 diameter of orifice	
Diverging cone, length 9 diameters	146

The velocity of flow of water in a full smooth cast-iron pipe of uniform diameter, is given by the formula, (Hawksley).

$$v = 48 \sqrt{\frac{h}{l} \times d} \quad (2)$$

Mr. Downing employs the same formula with the coefficient 50 instead of 48. His formula for the quantity of water discharged from a channel or pipe is,—

$$Q = 100a \sqrt{\frac{h}{l} \times D} \quad (3)$$

v = velocity, in feet per second.

h = head, in feet.

l = length, in feet.

d = diameter, in feet.

c = wetted perimeter, in feet.

a = sectional area of current, in square feet.

Q = quantity of water discharged, in cubic feet per second.

$D = \frac{a}{c}$ = hydraulic mean depth.

By the aid of Table 323, based on formula (3), the discharge, the diameter of pipe, and the fall are readily calculable.

1. *To find the rate of discharge*, when the length, fall, and diameter of pipe in feet are given. Find the tabular number next the diameter by the square root of the rate of inclination. The quotient is the rate of discharge in cubic feet per minute.

2. *To find the required diameter*, when the length and fall in feet, and the rate of discharge in cubic feet per minute, are given. Multiply the rate of discharge by the square root of the rate of inclination, find the product or the nearest value to it in the table. The diameter next to it is the diameter required, in feet.

3. *To find the required fall*, when the length and diameter

in feet, and the rate of discharge in cubic feet per minute are given. Divide the tabular number next the given diameter by the rate of discharge, square the quotient, and divide it by the length of pipe. The final quotient is the fall in feet.

Note. The rate of inclination is the quotient of the length by the vertical height.

Half the tabular number may be taken to find approximately the discharge for pipes half-full. The calculation is also available for sewers and the like.

TABLE 323.—DISCHARGE OF WATER IN PIPES.
(Turnbull.)

Diameter of Pipes.	Tabular Number	Diameter of Pipes.	Tabular Number	Diameter of Pipes.	Tabular Number
Inches.		Inches.		Inches.	
1	4.7	21	9544	42	53994
1½	18.6	22	10717	43	57250
2	26.4	23	11971	44	60625
3	73.6	24	13327	45	64142
4	130.7	25	14753	46	67750
5	262.9	26	16267	47	71494
6	416.3	27	17881	48	75391
7	611.4	28	19523	51	87713
8	852.8	29	21375	54	101190
9	1147.7	30	23282	57	115844
10	1492.1	31	25263	60	131700
11	1892	32	27335	66	167134
12	2356	33	29545	72	207752
13	2875	34	31826	78	253764
14	3459	35	34208	84	305384
15	4115	36	36726	90	362871
16	4806	37	39319	96	426436
17	5621	38	42018	102	496221
18	6492	39	44861	108	572343
19	7259	40	47674	114	655124
20	8439	41	50811	120	745014

Discharge of Water through Fire-hose and Nozzles.

In Tables 326 and 327, are given the actual discharge of water through small nozzles and long-nozzles connected to 2½-inch hose, 50 feet and 100 feet long.

In Table 328, are given the loss of head by friction in fire hose, of rubber and of leather, under given heads and rates of discharge.

TABLE 324. PRESSURE OF WATER FOR GIVEN HEADS.

Head.		Head.		Head.		Head.	
Pressure per square inch.		Pressure per square inch.		Pressure per square inch.		Pressure per square inch.	
Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.
1	0.43	41	17.75	81	35.08	121	52.41
2	0.86	42	18.19	82	35.52	122	52.84
3	1.30	43	18.62	83	35.95	123	53.28
4	1.73	44	19.05	84	36.39	124	53.71
5	2.16	45	19.49	85	36.82	125	54.15
6	2.59	46	19.92	86	37.25	126	54.58
7	3.03	47	20.35	87	37.68	127	55.01
8	3.46	48	20.79	88	38.12	128	55.44
9	3.89	49	21.22	89	38.55	129	55.88
10	4.33	50	21.65	90	38.98	130	56.31
11	4.76	51	22.09	91	39.42	131	56.74
12	5.20	52	22.52	92	39.85	132	57.18
13	5.63	53	22.95	93	40.28	133	57.61
14	6.06	54	23.39	94	40.72	134	58.04
15	6.49	55	23.82	95	41.15	135	58.48
16	6.93	56	24.26	96	41.58	136	58.91
17	7.36	57	24.69	97	42.01	137	59.34
18	7.79	58	25.12	98	42.45	138	59.77
19	8.22	59	25.55	99	42.88	139	60.21
20	8.66	60	25.99	100	43.31	140	60.64
21	9.09	61	26.42	101	43.75	141	61.07
22	9.53	62	26.85	102	44.18	142	61.51
23	9.96	63	27.29	103	44.61	143	61.94
24	10.39	64	27.72	104	45.05	144	62.37
25	10.82	65	28.15	105	45.48	145	62.81
26	11.26	66	28.58	106	45.91	146	63.24
27	11.69	67	29.02	107	46.34	147	63.67
28	12.12	68	29.45	108	46.78	148	64.10
29	12.55	69	29.88	109	47.21	149	64.54
30	12.99	70	30.32	110	47.64	150	64.97
31	13.42	71	30.75	111	48.08	151	65.40
32	13.86	72	31.18	112	48.51	152	65.84
33	14.29	73	31.62	113	48.94	153	66.27
34	14.72	74	32.05	114	49.38	154	66.70
35	15.16	75	32.48	115	49.81	155	67.14
36	15.59	76	32.92	116	50.24	156	67.57
37	16.02	77	33.35	117	50.68	157	68.00
38	16.45	78	33.78	118	51.11	158	68.44
39	16.89	79	34.21	119	51.54	159	68.87
40	17.32	80	34.65	120	51.98	160	69.31

TABLE 324. PRESSURE OF WATER FOR GIVEN HEADS
(continued).

Head.	Pressure per Square Foot.	Head.	Pressure per Square Foot.	Head.	Pressure per Square Foot.	Head.	Pressure per Square Foot.
Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.
161	69.54	200	86.63	239	103.65	278	120.42
162	70.17	201	87.27	240	103.96	279	120.85
163	70.61	202	87.56	241	104.39	280	121.29
164	71.04	203	87.93	242	104.83	281	121.72
165	71.47	204	88.36	243	105.26	282	122.15
166	71.91	205	88.80	244	105.69	283	122.59
167	72.34	206	89.23	245	106.13	284	123.02
168	72.77	207	89.66	246	106.56	285	123.45
169	73.20	208	90.10	247	106.99	286	123.89
170	73.61	209	90.53	248	107.43	287	124.32
171	74.07	210	90.96	249	107.86	288	124.75
172	74.50	211	91.39	250	108.29	289	125.18
173	74.94	212	91.83	251	108.73	290	125.62
174	75.37	213	92.26	252	109.16	291	126.05
175	75.80	214	92.69	253	109.59	292	126.48
176	76.23	215	93.13	254	110.03	293	126.92
177	76.67	216	93.56	255	110.46	294	127.35
178	77.11	217	93.99	256	110.89	295	127.78
179	77.53	218	94.43	257	111.32	296	128.22
180	77.97	219	94.86	258	111.76	297	128.65
181	78.40	220	95.30	259	112.19	298	129.08
182	78.84	221	95.73	260	112.62	299	129.51
183	79.27	222	96.16	261	113.06	300	129.95
184	79.70	223	96.59	262	113.49	310	134.28
185	80.14	224	97.03	263	113.92	320	138.62
186	80.57	225	97.46	264	114.36	330	142.95
187	81.00	226	97.90	265	114.79	340	147.28
188	81.43	227	98.33	266	115.22	350	151.61
189	81.87	228	98.76	267	115.66	360	155.94
190	82.30	229	99.20	268	116.09	370	160.27
191	82.73	230	99.63	269	116.52	380	164.61
192	83.17	231	100.06	270	116.96	390	168.94
193	83.60	232	100.49	271	117.39	400	173.27
194	84.03	233	100.93	272	117.82	500	216.58
195	84.47	234	101.36	273	118.25	600	259.90
196	84.90	235	101.79	274	118.69	700	302.22
197	85.34	236	102.23	275	119.12	800	344.54
198	85.76	237	102.66	276	119.56	900	386.86
199	86.20	238	103.09	277	119.99	1000	429.18

[illegible]

TABLE 328.—LOSS OF PRESSURE BY FRICTION PER 100 FEET OF 2½-INCH FIRE HOSE, FOR GIVEN HEADS AND RATES OF DISCHARGE (Fanning)

Head Feet.	Diameter of Nozzle in Inches.									
	1 inch.					1½ inches.				
	Discharge Gals. per Min.	Loss of Head by Friction Hose Lbs.	Distance reached by Jet Feet.	Horizontal Distance Feet.	Vertical Distance Feet.	Discharge Gals. per Min.	Loss of Head by Friction Hose Lbs.	Distance reached by Jet Feet.	Horizontal Distance Feet.	Vertical Distance Feet.
10	9.5	4.35	5	5	43	11.8	8.70	71	71	43
20	10.4	6.40	66	66	62	14.7	10.15	13	13	63
30	12.0	8.40	107	107	70	16.3	13.00	113	113	81
40	14.2	10.20	136	136	94	18.2	17.05	132	132	97
50	15.5	12.80	142	142	108	20.0	20.50	148	148	112
60	16.9	14.80	140	140	131	21.8	24.00	138	138	125
70	18.2	17.00	108	108	131	23.6	27.00	117	117	117
80	19.2	19.00	178	178	140	24.9	30.00	186	186	148
90	20.2	21.50	186	186	148	25.5	33.00	193	193	157
100										
Head Feet.	1½ inches.									
	Discharge Gals.	Lbs.	Feet.	Feet.	Feet.	Gallons.	Lbs.	Feet.	Feet.	Feet.
10	142.5	10.28	73	43	17.5	17.5	15.00	75	43	44
20	175.0	17.64	96	61	210.8	210.8	22.00	100	65	65
30	20.7	20.85	118	82	244.2	244.2	20.40	124	86	86
40	22.8	25.40	138	90	23.1	23.1	20.50	146	102	102
50	24.7	30.50	156	115	24.8	24.8	24.20	166	118	118
60	26.7	36.00	172	126	25.5	25.5	26.70	184	117	117
70	28.5	41.81	184	142	31.3	31.3	30.00	200	141	141
80	30.6	48.45	198	164	37.2	37.2	33.00	216	158	158
90	31.9	50.00	207	167	38.5	38.5	35.00	224	167	167

TABLE 329 DISCHARGE OF WATER OVER WEIRS IN
STREAMS, FOR EACH INCH OF WIDTH.

Dis- charge per Minute per Inch Wide.	Depth on Weir	Dis- charge per Minute per Inch Wide.	Depth on Weir.	Dis- charge per Minute per Inch Wide.	Depth on Weir	Dis- charge per Minute per Inch Wide.
Cub. Ft.	Inches.	Cub. Ft.	Inches.	Cub. Ft.	Inches.	Cub. Ft.
.40	5 $\frac{1}{2}$	5.18	10	12.71	14 $\frac{1}{2}$	22.22
.43	5 $\frac{3}{8}$	5.36	10 $\frac{1}{8}$	12.83	14 $\frac{5}{8}$	22.51
.45	5 $\frac{1}{4}$	5.54	10 $\frac{1}{4}$	13.19	14 $\frac{3}{4}$	22.79
.46	5 $\frac{3}{16}$	5.72	10 $\frac{3}{16}$	13.43	14 $\frac{7}{8}$	23.08
.47	6	5.90	10 $\frac{1}{2}$	13.67	15	23.38
.48	6 $\frac{1}{8}$	6.00	10 $\frac{5}{8}$	13.93	15 $\frac{1}{8}$	23.53
.49	6 $\frac{1}{4}$	6.28	10 $\frac{3}{4}$	14.16	15 $\frac{1}{4}$	23.97
1.03	6 $\frac{3}{8}$	6.47	10 $\frac{7}{8}$	14.42	15 $\frac{3}{8}$	24.26
1.14	6 $\frac{1}{2}$	6.65	11	14.67	15 $\frac{1}{2}$	24.56
1.19	6 $\frac{5}{8}$	6.85	11 $\frac{1}{8}$	14.79	15 $\frac{5}{8}$	24.86
1.26	6 $\frac{3}{4}$	7.05	11 $\frac{1}{4}$	15.18	15 $\frac{3}{4}$	25.16
1.47	6 $\frac{7}{8}$	7.25	11 $\frac{3}{8}$	15.43	15 $\frac{7}{8}$	25.46
1.59	7	7.44	11 $\frac{1}{2}$	15.67	16	25.76
1.71	7 $\frac{1}{8}$	7.74	11 $\frac{5}{8}$	15.96	16 $\frac{1}{8}$	25.91
1.83	7 $\frac{1}{4}$	7.84	11 $\frac{3}{4}$	16.20	16 $\frac{1}{4}$	26.36
1.96	7 $\frac{3}{8}$	8.15	11 $\frac{7}{8}$	16.46	16 $\frac{3}{8}$	26.66
2.09	7 $\frac{1}{2}$	8.25	12	16.73	16 $\frac{1}{2}$	26.97
2.16	7 $\frac{5}{8}$	8.45	12 $\frac{1}{8}$	16.86	16 $\frac{5}{8}$	27.27
2.36	7 $\frac{3}{4}$	8.66	12 $\frac{1}{4}$	17.26	16 $\frac{3}{4}$	27.58
2.50	7 $\frac{7}{8}$	8.86	12 $\frac{3}{8}$	17.52	16 $\frac{7}{8}$	27.89
2.63	8	9.10	12 $\frac{1}{2}$	17.78	17	28.20
2.78	8 $\frac{1}{8}$	9.25	12 $\frac{5}{8}$	18.05	17 $\frac{1}{8}$	28.35
2.92	8 $\frac{1}{4}$	9.52	12 $\frac{3}{4}$	18.32	17 $\frac{1}{4}$	28.82
3.07	8 $\frac{3}{8}$	9.74	12 $\frac{7}{8}$	18.58	17 $\frac{3}{8}$	29.14
3.22	8 $\frac{1}{2}$	9.96	13	18.87	17 $\frac{1}{2}$	29.45
3.29	8 $\frac{5}{8}$	10.18	13 $\frac{1}{8}$	19.31	17 $\frac{5}{8}$	29.76
3.52	8 $\frac{3}{4}$	10.40	13 $\frac{1}{4}$	19.42	17 $\frac{3}{4}$	30.38
3.68	8 $\frac{7}{8}$	10.62	13 $\frac{3}{8}$	19.69	17 $\frac{7}{8}$	30.39
3.83	9	10.86	13 $\frac{1}{2}$	19.97	18	30.70
3.99	9 $\frac{1}{8}$	10.97	13 $\frac{5}{8}$	20.24	18 $\frac{1}{8}$	30.86
4.16	9 $\frac{1}{4}$	11.31	13 $\frac{3}{4}$	20.52	18 $\frac{1}{4}$	31.31
4.32	9 $\frac{3}{8}$	11.54	13 $\frac{7}{8}$	20.80	18 $\frac{3}{8}$	31.66
4.50	9 $\frac{1}{2}$	11.77	14	21.09	18 $\frac{1}{2}$	31.98
4.58	9 $\frac{5}{8}$	12.00	14 $\frac{1}{8}$	21.23	18 $\frac{5}{8}$	32.31
4.84	9 $\frac{3}{4}$	12.23	14 $\frac{1}{4}$	21.65	18 $\frac{3}{4}$	32.63
5.01	9 $\frac{7}{8}$	12.47	14 $\frac{3}{8}$	21.93	18 $\frac{7}{8}$	32.96

Measurement of Water in a Stream.

To measure the volume of water flowing past a given point in a stream per minute, select a portion of the stream, uniform or nearly uniform in width, throw into the middle of the stream, a floating body sufficiently heavy to be almost totally immersed, as a bottle partly filled with water, and note the time taken to float from one mark to another; or, note the distance traversed by the float in one minute. The observation should be repeated several times to give an average result. Measure several sections of the stream within the measured distance, and multiply the average area in square feet by the distance in feet. From the volume thus calculated, one-fifth is deducted, as an allowance for retardation by frictional resistance at the bottom and sides, to give the volume of flow in cubic feet per minute.

Another method of measurement, admitting of more nearly exact results, is to cause the water to flow over a weir, by fixing a board across the stream where it flows slowly, having a notch cut into it broad enough and deep enough for all the water to pass over and fall freely. At the distance of a yard or two from the notch, up-stream, fix a rod, and mark on it the level of the crest of the notch, measure the height of the water surface above this mark, to give the depth of the crest below the surface of the water. Find in the Table 329, calculated according to Du Buat's formula, the observed depth in inches, and multiply it by the corresponding value in the next column, which expresses the volume discharged for each inch in width of the crest. The product is the whole volume of water discharged in cubic feet per minute.

For example, if the depth over a weir 50 inches wide be $6\frac{1}{2}$ inches, find $6\frac{1}{2}$ inches in the columns of depths, and note in the next column the quantity of water, 6.65 cubic feet per inch wide per minute. Multiply 6.65 by 50; the product is 332.5 cubic feet, the volume discharged per minute.

Discharge of Water from a Tank over a Tumbling Bay.

Messrs. B. Donkin & Co. have made observations of the quantity of water discharged from a tank, over a rectangular notch, tumbling bay or weir, cut into a brass or copper sheet, $\frac{1}{8}$ inch thick, fastened to the inside of the tank. The bay was 6 inches wide. The levels of water were observed on the same system as already described for the measurement of streams. The width of the bay should not in any case be greater than one-third of the width of the tank. Table 330 gives the weight and volume of water falling over a bay 6 inches wide,

minute, for depths of from $1\frac{1}{2}$ inches to $4\frac{1}{2}$ inches over bays of greater width than 6 inches, the rate of discharge is increased in the same proportion.

TABLE 330.—QUANTITY OF WATER DISCHARGED OVER A TUMBLING BAY, 6 INCHES WIDE
(Donkin.)

Depth over Tumbling Bay			Depth over Tumbling Bay		
Inches.	Pounds.	Cub. Ft.	Inches.	Pounds.	Cub. Ft.
$1\frac{1}{2}$	274	4.39	$3\frac{1}{2}$	874	14.00
$1\frac{5}{16}$	292	4.67	$3\frac{5}{16}$	900	14.43
$1\frac{3}{8}$	310	4.96	$3\frac{7}{8}$	926	14.83
$1\frac{11}{16}$	327	5.24	$3\frac{9}{8}$	951	15.21
$1\frac{1}{4}$	345	5.52	$3\frac{1}{2}$	977	15.65
$1\frac{13}{16}$	365	5.84	$3\frac{11}{16}$	1003	16.08
$1\frac{3}{4}$	384	6.13	$3\frac{3}{8}$	1030	16.44
$1\frac{15}{16}$	402	6.44	$3\frac{1}{2}$	1056	16.84
2	421	6.74	$3\frac{5}{8}$	1083	17.35
$2\frac{1}{16}$	442	7.08	$3\frac{13}{16}$	1112	17.82
$2\frac{1}{8}$	462	7.40	$3\frac{7}{8}$	1139	18.25
$2\frac{3}{16}$	483	7.74	$3\frac{15}{16}$	1166	18.68
$2\frac{1}{4}$	503	8.06	4	1193	19.11
$2\frac{5}{16}$	525	8.41	$4\frac{1}{16}$	1221	19.56
$2\frac{3}{8}$	547	8.76	$4\frac{1}{8}$	1250	20.01
$2\frac{7}{16}$	568	9.10	$4\frac{3}{16}$	1279	20.49
$2\frac{1}{2}$	589	9.43	$4\frac{1}{4}$	1306	20.93
$2\frac{9}{16}$	612	9.80	$4\frac{5}{16}$	1336	21.41
$2\frac{5}{8}$	634	10.16	$4\frac{3}{8}$	1365	21.87
$2\frac{11}{16}$	657	10.56	$4\frac{7}{16}$	1394	22.34
$2\frac{3}{4}$	680	10.89	$4\frac{1}{2}$	1424	22.82
$2\frac{13}{16}$	704	11.28	$4\frac{9}{16}$	1454	23.30
$2\frac{7}{8}$	727	11.65	$4\frac{5}{8}$	1483	23.76
$2\frac{15}{16}$	751	12.05	$4\frac{1}{2}$	1514	24.26
3	775	12.41	$4\frac{3}{4}$	1544	24.74
$3\frac{1}{16}$	800	12.82	$4\frac{11}{16}$	1575	25.24
$3\frac{1}{8}$	825	13.22	$4\frac{3}{8}$	1605	25.72
$3\frac{3}{16}$	850	13.62	$4\frac{5}{8}$	1635	26.22

Messrs. Donkin and Salter made more recent measurements of the flow of water over a bay of rectangular form, $1\frac{1}{2}$ inches wide, out square out of sheet brass $\frac{1}{16}$ inch thick. They gave

$$Q = L \cdot 40.082 \sqrt{h^3} \quad (4)$$

Q = pounds of water discharged, per minute.

Flow of Water through a Submerged Weir.

Water Power.

The proportion of the horse-power of the fall that can be utilised depends upon the efficiency of the motor.

Water-Wheels.

Under-shot wheels, having radial floats, are from 10 feet to 25 feet in diameter, and have an efficiency of from 27 per cent. to 30 per cent.

Poncelet's under-shot wheels have curved floats. The efficiency is about 65 per cent. for falls of 4 feet or less; and from 55 per cent. to 50 per cent. for falls of from 6 feet to 6½ feet. The velocity of the floats should be 55 per cent. of that of the water.

Breast wheels have an efficiency of 70 per cent. when the height of the fall is about 8 feet; 50 per cent. for 4 feet of fall. The most suitable velocity of the floats is $4\frac{1}{2}$ feet per

second. The diameter should be at least $11\frac{1}{2}$ feet; it is seldom more than double this.

Over-shot wheels are employed for heads of from 13 feet to 20 feet. The velocity of the floats should be at least 3 feet per second, say $6\frac{1}{2}$ feet for the smaller diameters, 10 feet for the larger diameters. The efficiency is from 70 per cent. to 75 per cent.

Whitclaw's water-mill—a development of Barker's mill—has been proved experimentally to show 76 per cent. of efficiency. In ordinary, the efficiency is about 55 per cent.

The Fourneyson turbine, having an outward flow, has an efficiency of from 60 per cent to 70 per cent. The Jonval turbine, having a downward flow, has usually 72 per cent. efficiency, under a full charge. It varies from 68 per cent to 80 per cent. The vortex wheel, or inward-flow turbine, designed by Mr James Thomson, has realised an efficiency of $77\frac{1}{2}$ per cent. The Swain turbine, in which an inward and a downward discharge are combined, when tested by Mr. J. B. Francis, realised a maximum efficiency of 84 per cent. At half gate the maximum efficiency was 78 per cent.

The Girard turbine, or tangential wheel, has yielded an efficiency of 87 per cent., at moderate speeds, in ordinary practice, from 75 per cent. to 80 per cent.

Hydraulic Power.

The Armstrong hydraulic machines work with efficiency varying with the multiplying gear, as follows :—

	Efficiency per cent.		Efficiency per cent.
Direct acting	93	10 to 1	63
2 to 1	80	12 to 1	59
4 to 1	76	14 to 1	54
6 to 1	72	16 to 1	50
8 to 1	67		

Conditions.—Ordinary pump packing, with sheaves and wrought-iron pins. With special precautions, comprising large sheaves, and small hard pins, the efficiency of a machine multiplying 20 to 1 was as high as 66 per cent. With the accumulator rising or falling, at 700 lbs. pressure per square inch, the friction of the ram is about $2\frac{1}{2}$ per cent.

The loss by friction in a steam-engine pumping into an accumulator, has been taken at 8.3 per cent. The ultimate efficiency is given by compounding the engine efficiency with the efficiency of the machine.

The ram of the hydraulic press is packed with a leather collar, the friction of which is,—

1 per cent. of the pressure for a 4-inch ram.

$\frac{1}{2}$	"	"	"	"	8	"
$\frac{1}{4}$	"	"	"	"	16	"

Hydraulic Transmission of Motive Power.

At the Central Pumping Station, Falcon Wharf, Blackfriars, of the London Hydraulic Power Company, there are two accumulators having 20-inch rams of 23-feet stroke, loaded for a pressure of 750 lbs. per square inch. At the Philip Lane Pumping Station, the accumulator is 13 feet above those, and is loaded to 710 lbs. per square inch. The delivery of power-water from Falcon Wharf is through four 6-inch mains; and, at 200 yards distance, through five 6-inch mains. The delivery is 1040 gallons per minute, at a velocity averaging 2.83 feet per second, or 170 feet per minute. The loss of head due to this velocity is 22.896 feet per 1000 yards, by the formula:—

$$\frac{(\text{Gallons per minute})^2 \times \text{length of pipe in yards}}{(3 \times \text{diameter of pipe in inches})^5}$$

The most distant point of the main is 5320 yards, or just over 3 miles, from the accumulators. In a circuit of 5 miles, the normal difference of pressure, or loss of head, was 20 feet head. To allow for such losses, as well as for valve passages and bends, the stated pressure supplied is 700 lbs. per square inch. At the end of 1887, the total length of mains laid was nearly 27 miles. There were then about 600 machines working from the mains in London, when the largest quantity of power delivered in one week was a little over 2,000,000 gallons, or 3,333 gallons per machine. The maximum consumption in any one hour was 35,000 gallons; the minimum, 1500 gallons. The practical efficiency—brake horse-power of hydraulic motors—may be fixed, says Mr. E. B. Ellington, the engineer of the company, at from 50 to 60 per cent. of the indicator power developed at the central station.

By the results of special trials, when 178½ indicator horse-power was developed, 4558 gallons of water were pumped per cwt. of coal consumed, with the Vicars stoker; 2.19 pounds of rough small coal being consumed per indicator horse-power per hour. In a trial for one week, under ordinary conditions, 3399 gallons of water were pumped per cwt. of coal consumed.

TABLE 331.—SPEEDS OF CUTTING TOOLS. (J. Roze.)

Work Diameter. Inches.	Roughing Cuts. Feet per Minute.	Roughing Cuts. Lathe Revolutions per Minute.	Feed or Lathe Revolutions per Inch of Tool Travel.	Finishing Cuts. Lathe Revolutions per Minute.	Finishing Cuts. Lathe Revolutions per Inch Tool Travel.
WROUGHT IRON.					
$\frac{1}{2}$	40	305	30	305	60
1	35	183	30	133	60
$1\frac{1}{2}$	30	76	30	76	60
2	28	53	25	53	60
$2\frac{1}{2}$	28	42	25	42	50
3	28	35	25	35	50
$3\frac{1}{2}$	26	28	25	30	50
4	26	24	20	26	50
5	25	18	20	21	50
6	25	15	20	16	50
CAST IRON.					
1	45	163	30	163	40
$1\frac{1}{2}$	45	135	25	135	30
2	40	76	25	76	25
$2\frac{1}{2}$	40	61	20	61	20
3	35	44	20	50	16
$3\frac{1}{2}$	35	38	18	48	16
4	35	33	18	38	16
$4\frac{1}{2}$	30	25	16	28	14
5	30	22	16	26	14
$5\frac{1}{2}$	30	20	14	24	12
6	30	19	14	22	12
BRASS.					
$\frac{1}{2}$	120	910	25	910	40
$\frac{3}{4}$	110	556	25	556	40
1	100	382	25	382	40
$1\frac{1}{4}$	90	275	25	275	40
$1\frac{1}{2}$	80	203	25	203	40
$1\frac{3}{4}$	80	174	25	174	40
2	75	143	25	143	40
$2\frac{1}{2}$	75	114	25	114	40
3	70	89	25	89	40
$3\frac{1}{2}$	70	76	25	76	40
4	70	66	25	66	40
$4\frac{1}{2}$	65	55	25	55	40
5	65	50	25	50	40
$5\frac{1}{2}$	65	45	25	45	40
6	65	41	25	41	40
TOOL STEEL.					
$\frac{1}{2}$	24	245	60	245	60
$\frac{3}{4}$	24	184	60	184	60
1	24	147	50	147	60
$1\frac{1}{4}$	24	122	40	122	60
$1\frac{1}{2}$	20	87	30	87	60
1	20	76	30	76	60
$1\frac{1}{4}$	20	61	25	61	50
$1\frac{1}{2}$	18	45	25	45	50
2	18	34	25	34	50
$2\frac{1}{4}$	18	27	25	27	50
3	18	22	25	22	50
$3\frac{1}{2}$	18	19	25	19	50
4	18	17	25	17	50
$4\frac{1}{2}$	18	15	25	15	50

Speed of Cutting Tools.

For cast-iron, 150 to 190 inches per minute, boring, 80 inches per minute.

For wrought-iron, 260 to 280 inches per minute.

For yellow brass, 300 inches per minute.

Wood-Working Machinery.

	Feet per Minute
Teeth of circular saws	9,000
Cutter blocks for planing and moulding (cutting edge)	6,000
Irregular moulding and shaping machines (ditto)	5,000
Band-saw for cutting metals	250
Band-saw blades	4,000
Saw and cutter sharpening machine	5,000
Shafting	250 revolutions

COLOURS.

TABLE 332.—COLOURS USED IN MECHANICAL AND ARCHITECTURAL DRAWING, TO REPRESENT VARIOUS MATERIALS.

Materials.	Colours used.
Brass	Gamboge.
Brick work (in section)	Crimson lake.
Brickwork (in elevation)	Crimson lake, mixed with burnt sienna.
Cement	Sepia.
Concrete	Sepia, mottled, with burnt umber.
Copper	Crimson lake, mixed with gamboge.
Glass	Cobalt (blue), mottled.
Iron (wrought)	Prussian blue.
Iron (cast)	Payne's grey.
Lead	Indigo, or light Indian ink.
Leather	Vandyke brown.
Plaster	Sepia.
Slate	Indigo, mixed with crimson lake.
Steel	Crimson lake, mixed with Prussian blue.
Stone	Burnt umber.
Tiles	Indian red.
Wood	Burnt sienna.

ELECTRICAL ENGINEERING.

Electrical Units.

Unit.	Name.	Derivation.	Dimensions in C. G. S.* Units.
Electromotive Force . . .	Volt . . .	Ampère \times Ohm	10^8
Resistance . . .	Ohm . . .	Volt \div Ampère .	10^9
" . . .	Megohm	1 million Ohms	10^{12}
Current . . .	Ampère . . .	Volt \div Ohm	10^{-1}
" . . .	Milliampère .	1 thousandth Ampère .	10^{-4}
Quantity . . .	Coulomb	Ampère \times Second	10^{-1}
Capacity . . .	Farad . . .	Coulomb \div Volt	10^{-9}
" . . .	Microfarad .	1 millionth Farad . . .	10^{-12}

* C. G. S. - Centimètre-Gramme-Second.

For electric light and power purposes the Ampère is the practical unit of current.

For telegraph purposes the Milliampère is the practical unit of current.

The B.A. (British Association) Ohm, the unit of resistance in general use - resistance of column of pure mercury 104.82 metres long, 1 sq. mm section at 0° C.; it is less in value than the true Ohm, which according to most recent determinations is $\frac{1.0627}{1.0482}$ of the B.A. Ohm.

The Siemens Mercury Unit - .9340 B.A. Unit.

Insulation resistances are usually measured in Megohms.

When a current of 1 Ampère flows, electricity is passing at the rate of 1 Coulomb per second.

A capacity of 1 Farad charged to a potential of 1 Volt contains 1 Coulomb of electricity.

The Microfarad is the practical unit of capacity ; it is the capacity of about $\frac{1}{3}$ rd of a mile of submarine cable.

A Daniell Cell has roughly an Electromotive Force of 1.07 Volts.

Electro-Mechanical Units.

Rate at which work is being done or energy expended in a resistance, R , through which a current, C , is flowing, there being an electromotive force or potential difference, E , between the ends of the resistance is

$$EC, C^2 R, \text{ or } \frac{E^2}{R}, \text{ Watts.}$$

1 Watt = $\frac{1}{746}$ th of a horse-power, i.e., 1 horse-power = 746 Watts.

1 Kilowatt = 1000 Watts = 1.34 horse-power.

1 Watt = 1 Joule per sec.

A current of 1 Ampère flowing through a resistance of 1 Ohm for 1 sec. does 1 Joule of work.

1 Joule will raise .238 grammes of water 1° C. in temperature.

1 Calorie is the amount of heat required to raise 1 gramme of water 1° C.

1 Joule = .238 calories.

1 Joule = .7373 foot-lbs. = 10,000,000 Ergs.

1 Erg (the absolute unit of *work*) = 1 Centimètre-dyne.

1 Dyne (the absolute unit of *force*) is that force which, acting for 1 sec. on a weight of 1 gramme on a smooth horizontal plane, will give it a velocity of 1 centimètre per sec.

Board of Trade unit = 1000 Watt-hours = work done by 1.34 horse-power during 1 hour.

Measurement of Resistances.

For general purposes, the measurement of resistances is most conveniently effected by the Post Office pattern of Wheatstone bridge, the plan of connections of which is shown Fig. 81.

Wheatstone Bridge.

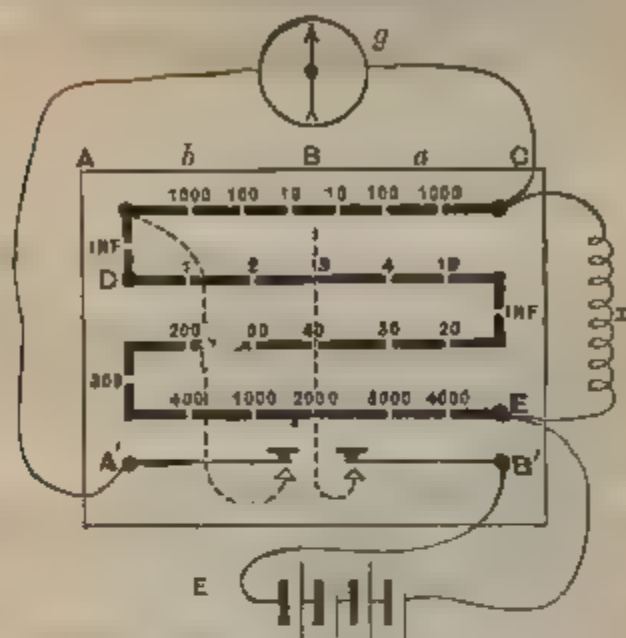
Post Office Pattern.

FIG. 84.

x is the resistance to be measured, g a galvanometer of about 1000 ohms resistance, and E a battery (which for ordinary purposes may be about 10 Leclanche cells). In making a measurement plugs must be removed from a and b , and the right hand key pressed and kept down, then the left hand key must be alternately depressed and raised, plugs being removed from between D and E until no movement of the galvanometer needle is observed to take place on the depression and raising of the key. When balance is thus obtained

$$x = \frac{a}{b} r$$

r being the resistance unplugged between D and E (the greatest value of this resistance is 10,000 ohms). By making a greater than b resistances greater than the whole of the resistance between D and E , i.e., 10,000 ohms can be measured, the greatest value being 1,000,000 ohms, which is obtained by making $a = 1000$ and $b = 10$, for when $r = 10,000$ ohms, then

$$x = \frac{1000}{10} \times 10,000 = 1,000,000 \text{ ohms.}$$

By making a less than b resistances less than 1 ohm can be measured, the least value being .01 ohm, which is obtained by making $a = 10$ and $b = 1000$, for when $r = 1$ ohm, then

$$x = \frac{10}{1000} \times 1 = .01 \text{ ohms.}$$

Individual Resistance of 3 or more Telegraph Wires.

In order to avoid errors due to earth currents or an imperfect earth when measuring the conductor resistance of 3 or more telegraph wires,

Loop wires 1 and 2 and let measured resistance be r_1

" " 1 " 3 " " " " r_2

" " 2 " 3 " " " " r_3

then

$$\text{Resistance of No. 1. Wire} = \frac{r_1 + r_2 - r_3}{2}$$

" " 2 " $= r_1$ - Resistance of No. 1 Wire

" " 3 " $= r_2$ - " " 2 "

As the resistance of No. 1 wire is thus known we can loop it with any number of other wires, and having ascertained the resistances of the loops, the resistance of any one of the wires is given by subtracting the resistance of No. 1 wire from the resistance of the loop.

Measurement of Low Resistances.

For measuring low resistances—*i.e.* resistances of less than 1 ohm—with accuracy, the measurements are usually made by means of the "Metre" bridge:—

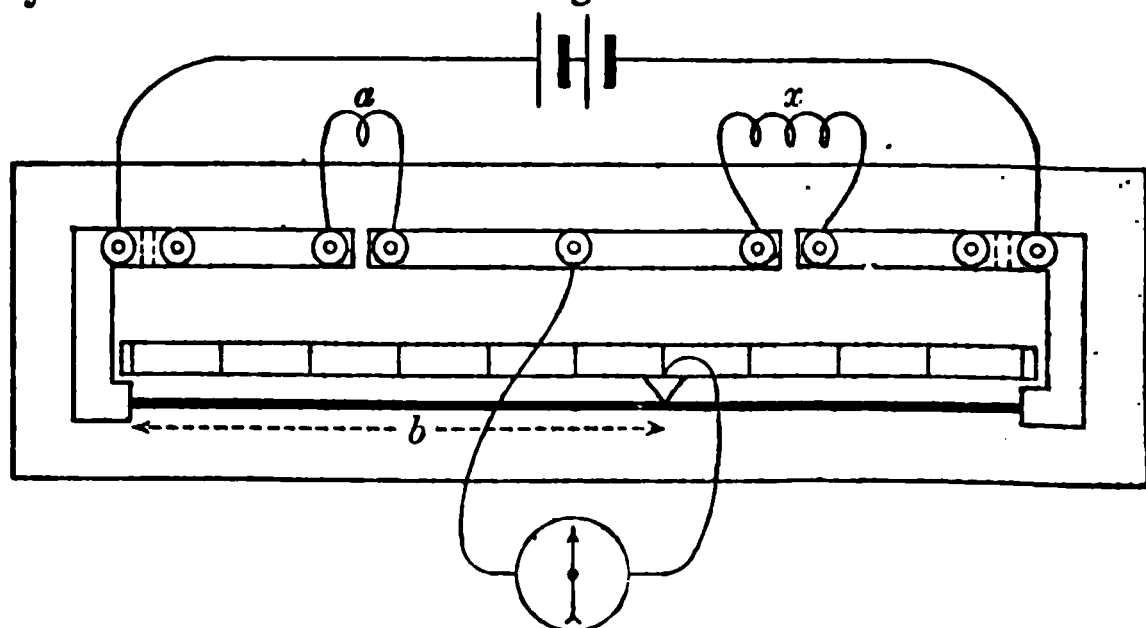


FIG. 82.

a is a standard resistance of 1 ohm, x is the low resistance to be measured. A slider connected to one end of the galvanometer is moved until no movement of the needle takes place on depressing the slider contact, then

$$x = \frac{1000}{b} - 1$$

The galvanometer should have a resistance of about $\frac{1}{10}$ th ohm, and the battery should be about 2 large size Leclanché cells. Great care should be taken that all the connections to the terminals are well made, and that the surfaces in contact are scraped bright.

Measurement of High Resistances.

For measuring high resistances, *i.e.* resistances exceeding 1 megohm, such as the *Insulation resistance* of a well insulated wire, the bridge method cannot be adopted with accuracy; in these cases the "deflection" method must be used, and a galvanometer of high resistance and one in which the deflections are directly proportional to the current, be employed. The galvanometer most suitable for the purpose is the "Thomson Reflecting."

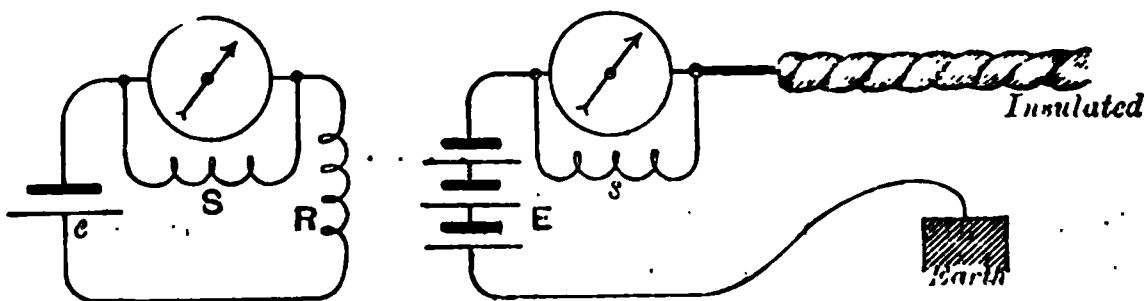


FIG. 83.

A small battery e (usually 1 cell) is first connected up with the galvanometer and with a resistance R of 10,000 ohms (the resistance between D and E of the Post Office Wheatstone bridge may be used for the purpose), the galvanometer being shunted by a shunt S (usually the $\frac{1}{1000}$ th shunt) so that a convenient deflection D is obtained; this is called taking the *constant*. The connections are then altered as shown by the second fig., a large battery E (about 100 or more cells) being used, and the wire whose insulation is to be measured being joined up as shown. Let the deflection be d , and the shunt, s , on the galvanometer be the $\frac{1}{n}$ th (usually $\frac{1}{10}$ th, $\frac{1}{100}$ th or $\frac{1}{1000}$ th, *i.e.* $n=10, 100, \text{ or } 1000$): also let the shunt used when the *constant* is taken be the $\frac{1}{N}$ th shunt, then

$$\text{Insulation resistance of wire} = \frac{D \times N}{d} \times K$$

where K is the ratio between the number of cells used in taking D and in taking the constant; thus if d is given by 100 cells and D by 1 cell, then $K=100$. When great accuracy is required, the exact ratio of the force of the large to the small battery has to be determined, for it is seldom that 100 cells have exactly 100 times the force of 1 cell, though in a large number of cases it is sufficient to consider it as such, care being taken that the cells are all in good condition. If a megohm resistance (1,000,000 ohms) is available, the constant may be taken with the same battery as is used for testing the insulated wire, the megohm being used in the place of the 10,000 ohms. In this case $K=1$.

Care should be taken that the ends of the insulated wire being tested are well trimmed and quite dry; preferably the ends should be painted over with, or dipped for a moment in, hot paraffin *wax*, not paraffin oil.

Combined Resistances.

The joint resistance of any number of resistances joined in parallel or multiple arc, is equal to the reciprocal of the sum of the reciprocals of their respective resistances; thus the joint resistance in parallel of wires whose resistances are r_1, r_2, r_3, r_4 , &c., is

$$\frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \frac{1}{r_4} + \dots}$$

If there are only *two* resistances, then their joint resistance in parallel is equal to the product of their values divided by their sum, or

$$\frac{r_1 r_2}{r_1 + r_2}$$

Shunts.

If C = total current flowing through a galvanometer of resistance G shunted by a resistance S , and c the portion of this current flowing through the galvanometer, then

$$C = c \frac{G + S}{S}$$

$\frac{G + S}{S}$ is called the *multiplying power* of the shunt.

The joint resistance of the galvanometer and shunt is

$$\frac{GS}{G + S}.$$

The shunt required to give a certain multiplying power n is

$$\frac{G}{n - 1}.$$

The joint resistance of the shunt and galvanometer in this case is

$$\frac{G}{n}.$$

If it is required to make up for the reduction of resistance in the circuit caused by the addition of the shunt, a *compensating* resistance,

$$\frac{G^2}{G + S}, \text{ or } G \frac{n - 1}{n}$$

must be added in the circuit.

Ratio of Current to Resistance and Potential Difference.

C = current flowing through a wire,

V = potential difference between its ends,

R = resistance of wire,

$$C = \frac{V}{R}, R = \frac{V}{C} \quad V = C R.$$

Corrections for Temperature.

For general Telegraphic and Electric Light purposes, the resistances of copper conductors are reduced or corrected from the measured results at the observed temperature to the values at 60° F., this being the normal temperature of the air, this reduction can be effected by the following table. —

TABLE 333. MULTIPLYING COEFFICIENTS FOR REDUCING THE OBSERVED RESISTANCE OF ORDINARY COPPER WIRE AT ANY TEMPERATURE TO 60° F.

Temp. F.	Coeff.	Temp. F.	Coeff.	Temp. F.	Coeff.	Temp. F.	Coeff.	Temp. F.	Coeff.
90	9392	79	9610	68	9834	57	1 006	46	1 029
89.5	9402	78.5	9621	67.5	9844	56.5	1 007	45	1 030
89	9412	78	9631	67	9855	56	1 008	45.5	1 031
88.5	9421	77.5	9641	66.5	9865	55.5	1 009	45	1 032
88	9431	77	9651	66	9875	55	1 010	44.5	1 033
87.5	9441	76.5	9661	65.5	9886	54.5	1 012	44	1 034
87	9451	76	9671	65	9896	54	1 013	43.5	1 035
86.5	9461	75.5	9681	64.5	9906	53.5	1 014	43	1 036
86	9471	75	9691	64	9917	53	1 015	42.5	1 037
85.5	9481	74.5	9701	63.5	9927	52.5	1 016	42	1 038
85	9491	74	9711	63	9937	52	1 017	41.5	1 039
84.5	9501	73.5	9721	62.5	9948	51.5	1 018	41	1 041
84	9510	73	9732	62	9958	51	1 019	40.5	1 042
83.5	9520	72.5	9742	61.5	9969	50.5	1 020	40	1 043
83	9530	72	9752	61	9979	50	1 021	39.5	1 044
82.5	9540	71.5	9762	60.5	9990	49.5	1 022	39	1 045
82	9550	71	9772	60	1 000	49	1 023	38.5	1 046
81.5	9560	70.5	9783	59.5	1 001	48.5	1 024	38	1 047
81	9570	70	9793	59	1 002	48	1 025	37.5	1 048
80.5	9580	69.5	9803	58.5	1 003	47.5	1 026	37	1 049
80	9590	69	9814	58	1 004	47	1 027	36.5	1 050
79.5	9600	68.5	9824	57.5	1 005				

Example. The resistance of a copper wire at 48° F. is 200 ohms: what is its resistance at 60° F.?

Resistance at 60° F. = 200 × 1 025 = 205.0 ohms.

For Submarine Cable tests the results are reduced to 75° F. by the following table:—

TABLE 334.—MULTIPLYING COEFFICIENTS (k) FOR REDUCING THE OBSERVED RESISTANCE OF ORDINARY COPPER WIRE AT ANY TEMPERATURE TO 75° F.

Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.
90	·9691	79	·9917	68	1·015	57	1·038	46·5	1·061
89·5	·9701	78·5	·9927	67·5	1·016	56·5	1·039	46	1·062
89	·9711	78	·9937	67	1·017	56	1·041	45·5	1·064
88·5	·9722	77·5	·9948	66·5	1·018	55·5	1·042	45	1·065
88	·9732	77	·9958	66	1·019	55	1·043	44·5	1·066
87·5	·9742	76·5	·9969	65·5	1·020	54·5	1·044	44	1·067
87	·9752	76	·9979	65	1·021	54	1·045	43·5	1·068
86·5	·9762	75·5	·9990	64·5	1·022	53·5	1·046	43	1·069
86	·9772	75	1·000	64	1·023	53	1·047	42·5	1·070
85·5	·9783	74·5	1·001	63·5	1·024	52·5	1·048	42	1·071
85	·9793	74	1·002	63	1·025	52	1·049	41·5	1·072
84·5	·9803	73·5	1·003	62·5	1·026	51·5	1·050	41	1·074
84	·9814	73	1·004	62	1·027	51	1·051	40·5	1·075
83·5	·9824	72·5	1·005	61·5	1·029	50·5	1·053	40	1·076
83	·9834	72	1·006	61	1·030	50	1·054	39·5	1·077
82·5	·9844	71·5	1·007	60·5	1·031	49·5	1·055	39	1·078
82	·9855	71	1·008	60	1·032	49	1·056	38·5	1·079
81·5	·9865	70·5	1·009	59·5	1·033	48·5	1·057	38	1·080
81	·9875	70	1·010	59	1·034	48	1·058	37·5	1·082
80·5	·9886	69·5	1·012	58·5	1·035	47·5	1·059	37	1·083
80	·9896	69	1·013	58	1·036	47	1·060	36·5	1·084
79·5	·9906	68·5	1·014	57·5	1·037				

Example.—The resistance of a copper wire at 57° F. is 300 ohms; what is its resistance at 75° F.?

Resistance at 75° F. = $300 \times 1·038 = 311·4$ ohms.

By means of the foregoing Table the temperature of the Sea in which a Submarine Cable is laid can be determined, provided the resistance of the conductor of the Cable at 75° was ascertained during the course of manufacture. The measured resistance of the Cable when the latter is laid, divided into the resistance at 75° gives a coefficient which in the above Table corresponds to the temperature of the conductor, that is of the Sea.

The reduction to 75° of the Insulation (dielectric) tests is effected by the following table:—

TABLE 335. DIVIDING COEFFICIENTS FOR CORRECTING THE OBSERVED RESISTANCE OF GUTTA-PERCHA AT ANY TEMPERATURE TO 75° F

Temp. ° F.	Coef.	Temp. ° F.	Coef.	Temp. ° F.	Coef.	Temp. ° F.	Coef.	Temp. ° F.	Coef.
90	3197	80	6837	70	1463	60	3128	50	6692
89.5	3320	79.5	102	69.5	1519	59.5	3256	49.5	6951
89	3449	79	7378	69	1578	59	3376	49	7220
88.5	3583	78.5	7663	68.5	1639	58.5	3506	48.5	7500
88	3722	78	7960	68	1701	58	3642	48	7791
87.5	3866	77.5	8269	67.5	1769	57.5	3783	47.5	8093
87	4016	77	8589	67	1837	57	3930	47	8406
86.5	4171	76.5	8922	66.5	1908	56.5	4082	46.5	8732
86	4343	76	9267	66	1982	56	4240	46	9070
85.5	4501	75.5	9627	65.5	2059	55.5	4405	45.5	9422
85	4675	75	1000	65	2139	55	4575	45	9787
84.5	4856	74.5	1039	64.5	2222	54.5	4753	44.5	1017
84	5044	74	1079	64	2308	54	4937	44	1056
83.5	5240	73.5	1121	63.5	2397	53.5	5128	43.5	1097
83	5443	73	1164	63	2490	53	5327	43	1139
82.5	5654	72.5	1209	62.5	2587	52.5	5533	42.5	1184
82	5873	72	1256	62	2687	52	5748	42	1229
81.5	6100	71.5	1305	61.5	2792	51.5	5970	41.5	1277
81	6337	71	1355	61	2899	51	6202	41	1327
80.5	6582	70.5	1408	60.5	3012	50.5	6442	40.5	1378

Example. The insulation resistance at 62° F. of a wire insulated with gutta-percha is 500 megohms; what is the resistance at 75° F.?

$$\text{Resistance} = 500 \div 2.687 = 186.1 \text{ megohms.}$$

Fault Testing.

Blavier's Method.

Insulate further end of line and measure resistance l .

Put further end of line to earth, and measure resistance l_1 .

Resistance of line when good = L .

$$\text{Resistance up to fault} = l_1 - \sqrt{(l - l_1)(L - l_1)}.$$

Overlap Method.

Measure resistance l from station A, station B insulated.

Measure resistance l_2 from station B, station A insulated.

Resistance of line when good = L .

Resistance up to fault from station A = $\frac{L + l - l_2}{2}$

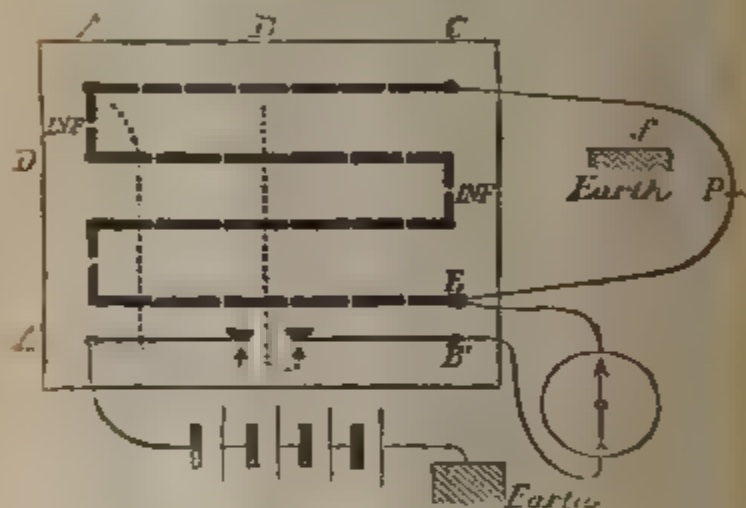
Murray's Loop Method.

FIG. 84.

C P faulty line. E F good line.

All plugs to be inserted between B and C, also plug between A and D.

10, 100, or 1000 plugs (according to length of loop) taken out between A and C.

Left-hand key to be held permanently down, and right-hand key to be manipulated.

D E to be adjusted till equilibrium is produced.

Resistance from C up to fault = $L \frac{b}{b+d}$

L = total resistance of entire loop (measured by bridge 599).

b = resistance unplugged in A B.

d = " " " D E.

Varley's Loop Method.

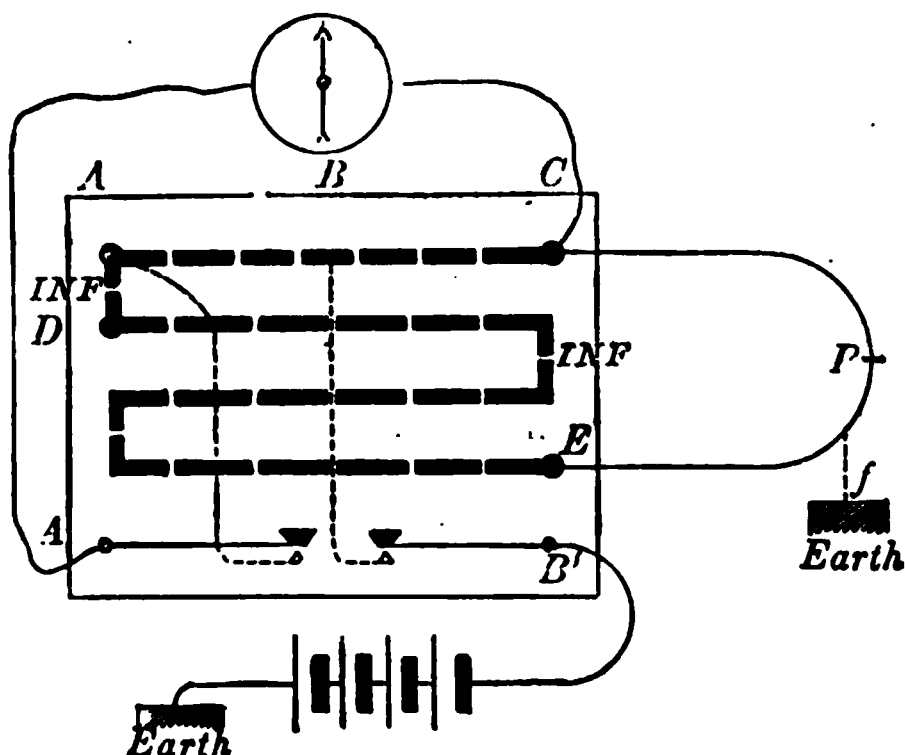


FIG. 85.

E P. faulty line. C P good line.

10, 100, or 1000 plugs (according to length of loop) to be taken out between A and B and between B and C.

Right-hand key to be held permanently down, and *left-hand* key to be manipulated.

D E to be adjusted till equilibrium is produced.

$$\text{Resistance from E up to fault} = \frac{bL - ad}{b + a}.$$

L = total resistance of entire loop (measured by bridge, page 599).

a = resistance unplugged in B C.

b = " " " A B.

d = " " " D E.

Inductive or Electrostatic Capacity.

Inductive capacities are measured by comparing the discharge from a standard condenser with the discharge from the insulated wire whose capacity is required; the capacities will be in direct proportion to the discharges if the latter are measured on a Thomson reflecting galvanometer.

Inductive capacity of a wire insulated with gutta-percha

$$= \frac{.170}{\log. \frac{D}{d}} \text{ m. farads per knot, approximately.}$$

$$= \frac{.147}{\log. \frac{D}{d}} \quad , \quad , \text{ statute mile } ,$$

where D = diameter of insulating material,

d = „ conductor.

For india-rubber the values are about 10 to 15 per cent less.

Specific inductive capacity of the material with which wire is insulated, *i.e.*, the capacity of a cube knot,

$$\begin{aligned} & \log. \frac{D}{d} \\ & = K \frac{D}{2.728} \end{aligned}$$

where K = capacity in microfarads per knot of the insulated wire.

Inductive capacity of an aerial line

$$= \frac{.061637}{\log. \frac{4h}{d}} \text{ m. farads per statute mile, approx.}$$

where d = diameter of wire in mils.

h = height of wire above ground, also in mils.

Electro-Chemistry.

One ampère of current decomposes .00009324 gramme of water per second, liberating .000010384 gramme of hydrogen and .00008286 gramme of oxygen.

C ampères of current in T seconds will throw down or deposit from a solution of any salt of a metal

CTa grammes, or CTb grains,

where a and b are the values given in the following Table

TABLE 336. VALUES OF a AND b , ELECTRO-CHEMICAL DEPOSITS.

Metal.	a (grammes).	b (grains).
Hydrogen	000010384	0.0016025
Aluminium	000009449	0014582
Magnesium	00012430	0019182
Iron (Ferric)	00019336	0029869
" (<i>Ferrous</i>)	00029035	0044808
Sodium	00023873	0036842
Nickel	00030425	0046953
Tin (Stannic)	00036581	0047085
" (<i>Stannous</i>)	00061162	0014387
Copper (Cupric)	00032709	0050478
" (<i>Cuprous</i>)	00065419	0100960
Zinc	00033606	0052081
Potassium	00041539	0062561
Gold	00067911	0104800
Mercury (Mercuric)	00163746	0160100
" (<i>Mercurous</i>)	00207470	0220170
Lead	00107150	0165370
Silver	00111800	0179540

Primary Batteries.

A current of 1 ampère for 1 hour in a primary battery will dissolve 1.213 grammes 18.72 grains of zinc in each cell, provided there is no local action.

Quantity of zinc consumed in a primary battery per horse-power-hour

$$= \frac{1.995}{E} \text{ lbs.},$$

where E is the electromotive force of the battery.

Quantity of any metal (used as the positive plate) consumed in a primary battery per horse-power-hour

$$= \frac{5921.8 \times a}{E} \text{ lbs.},$$

where a is the value given in the foregoing table

Weight for weight primary batteries contain a much greater storage of energy than *Accumulators*, but the energy being produced by the combustion of zinc and the decomposition of acids is more expensive to obtain.

Accumulators.

The largest size accumulators (Electric Power Storage Company) have a capacity of 660 ampere-hours, and weigh, when charged with acid, 265 lbs. The acid (acidulated water), weighs 73 lbs.; the approximate outside dimensions of the glass cells are,—length, 18½ inches, width, 11½ inches; height, 13½ inches, height over all, 15½ inches; each cell contains 31 plates. The cells are charged with a current of from 50 to 60 amperes, and discharged with a current not exceeding 60 amperes. The smaller cells are rather heavier in proportion.

Taking the plates alone, each 1 lb. weight of plates will store about 30,000 foot-pounds of energy.

The acidulated water contains 25 per cent. of sulphuric acid.

The cells should never be left standing uncharged, and should not be discharged to more than ⅓rds of their capacity; they should not be discharged beyond the maximum rate for which they are designed, *i.e.*, a cell which is intended to discharge at a maximum rate of 60 amperes should not be worked at 70 amperes as this would tend to spoil the cells.

About 80 per cent. of the charge can be obtained by discharge if the cells are in good condition.

The electromotive force of accumulators averages 2 volts, though the force is slightly higher when the cells are freshly charged.

The charging electromotive force should not exceed the electromotive force of the accumulator by more than 5 per cent.

If E = the full electromotive force of the charging dynamo and C = the current passing, the *total* rate at which work is being expended on the charging is

$$EC \text{ Watts;}$$

a portion of the work is wasted in heating the accumulator

The actual rate at which work is being accumulated in the accumulator is

$$E' C$$

where E' is the electromotive force at the accumulator terminals *when the latter are disconnected*.

In the use of accumulators there is first a loss in charging, the loss being due to waste in the dynamo and waste in the accumulator. there is also waste in the accumulator *on discharging* partly due to heating and partly to local action.

It is more economical to charge accumulators with a

current continued for a lengthened period than with a strong current for a short period.

The resistance of an accumulator (when discharging) is

$$\frac{E_1 - E_2}{C}$$

where E_1 is the electromotive force on open circuit, and E_2 the electromotive force on closed circuit.

The accumulator cells should be kept in as dry (but not warm) a situation as possible.

For charging accumulators a *shunt* wound dynamo must be used.

Current Induction.

If e = electromotive force set up in a rectilinear conductor of length l moving through a magnetic field of intensity H ,

v = velocity of moving conductor,

α = angle the conductor makes with the lines of force,

ϕ = angle between the direction of motion and the direction of the force exerted between the magnetic field and the conductor; then,

$$e = H l v \sin \alpha \cos \phi.$$

If the conductor is at right angles to and moves so as to cut the lines of force at right angles (in which case $\sin \alpha \cos \phi$ each equal 1), then 1 Gauss is the strength of field in which a length of one million centimetres of wire moving with unit velocity (1 centimetre per sec), develops 1 volt of electromotive force = 100 times the strength of 1 C. G. S. field.

The strongest field of a dynamo magnet is about 100 Gausses = $100 \times 100 = 10,000$ C. G. S. units.

1 C. G. S. magnetic field has 1 line of force per square centimetre.

1 Kapp line = 6,000 C. G. S. lines.

1 " " per square inch = 930 C. G. S. lines per square centimetre.

A magnetic field whose strength is 100 Gausses contains $10,000 = 10.75$ Kapp lines per square inch.

930

The Kapp line was proposed as a suitable factory unit because the revolutions of dynamo armatures are usually reckoned per minute instead of per second (60 secs. = 1 minute), and also by dividing by 100, the units expressed the number of magnetic lines are brought to numerical values easily dealt with and remembered.

DYNAMOS.

The Series Dynamo.



FIG. 85. Series Wound.

If R = external resistance.

r_a = resistance of armature.

r_m = resistance of field-magnet coils.

E = electromotive force of machine.

e = potential difference between terminals of machine.

c = current strength.

$$e = c R - E - (r_a + r_m) c$$

Ratio of useful electric energy available
in external circuit to total electric
energy developed

$$\frac{R}{R + r_a + r_m}$$

r_m may with advantage be made about two-thirds of r_a .

Series machines are used for running arc lamps directly.

The Shunt Dynamo.

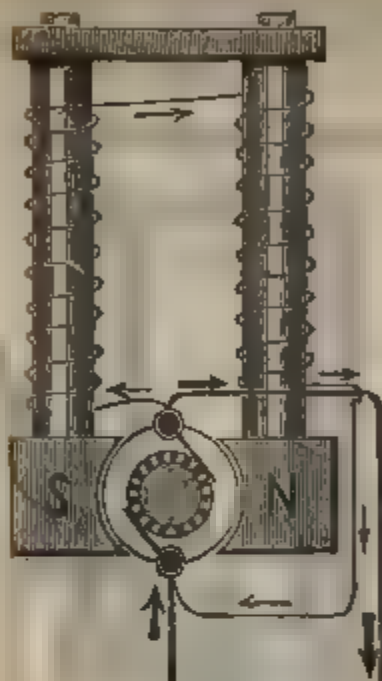


FIG. 37.—Shunt Wound.

If R = external resistance,

r_a = resistance of armature,

r_s = " " field-magnet coils,

E = electromotive force of machine,

e = potential difference between terminals of machine,

c = current in external circuit,

c_a = " " armature,

c_s = " " field-magnet coils,

$$e = cR = c_a r_a = E - r_s (c + c_s)$$

$$E = \left(r_a + \frac{R r_s}{R + r_s} \right) c_a = e r_s \left(\frac{1}{R} + \frac{1}{r_a} + \frac{1}{r_s} \right)$$

$$\text{Ratio of useful electric energy} \left\{ \begin{array}{l} \text{available in external circuit to} \\ \text{total energy developed} \end{array} \right. = \frac{C^2 R}{C^2 R + c_a^2 r_a + c_s^2 r_s}$$

In order that a shunt dynamo may give in the external circuit as much as 10 per cent. of its total electric energy the resistance of the shunt must be at least 364 times as great as that of the armature.

Practically the armature resistance may be made $\frac{1}{20}$ th of the external resistance, and the shunt resistance 20 times as great.

Shunt machines are used for charging accumulators and for electroplating.

Separately Excited Dynamos.

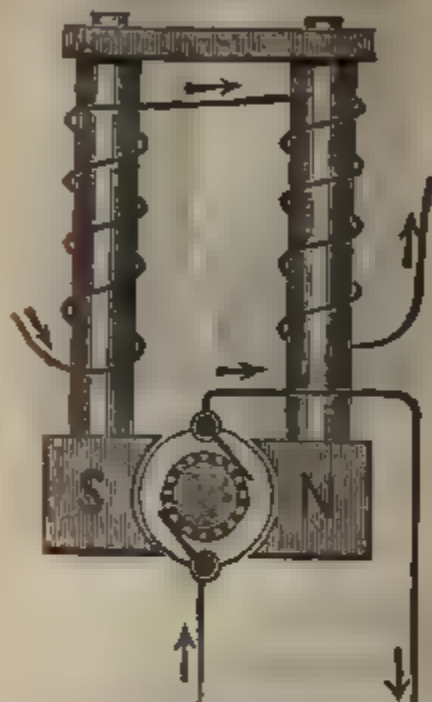


FIG. 88.—Separate Excitation.

If R = external resistance,

r_m = resistance of field-magnet coils,

E = electromotive force of machine,

c = current in external circuit,

c_m = " " field-magnets,

$$E = c R$$

Ratio of useful electric energy available
in external circuit to total energy
developed $\left\{ = \frac{C^2 R}{C^2 R + C_m^2 r_m} \right.$

This gives the distribution of the energy as far as the machine itself is concerned, but there is also a loss of energy in the dynamo used for exciting the field magnets which must be taken into account. This exciting dynamo may be used to excite the field magnets of several dynamos.

Compound Wound Dynamos.



FIG. 89.—Compound Wound

- If R = external resistance
 r_a = resistance of armature
 r_s = " " " field-magnet shunt coils.
 r_m = " " " " series "
 c = current in external circuit.
 c_a = " " " armature coils.
 c_s = " " " shunt "
 c_m = " " " series "

Ratio of useful electric energy available in external circuit to total energy developed

$$= \frac{c^2 R}{c^2 R + c_a^2 r_a + c_s^2 r_s + c_m^2 r_m}$$

r_s should be from 1,000 to 1,500 times r_a , and r_m about two-thirds r_s .

Compound machines enable a constant potential to be kept at their terminals irrespective of the work to be done in the external circuit. This is required in the case of an installation of incandescent lamps.

If E = electromotive force after time t .

C = current

T = half period of a complete alternation.

t = time from the instant at which the electromotive force was zero when charging from the direct current reckoned as negative to that reckoned as positive.

K = a constant

$$C = \frac{K}{T} \sin \frac{\pi}{T} t$$

If C_m = mean current during the time T .

$$C_m = \frac{2K}{\pi T}$$

When an alternating current passes through a wire, L is the resistance due to the self-induction in the wire whose ohmic resistance is R and self-induction L is

$$\frac{1}{T} \sqrt{R^2 T^2 + \pi^2 L^2}$$

If C' be the current indicated on an electro-dynamometer

$$C_m = \frac{9}{10} C'$$

Watts consumed in lamps
worked with alternating
currents

$$\frac{r T \sqrt{A^2 V^2}}{\sqrt{\frac{1}{2} \pi^2 + r^2 T^2}}$$

Where A = mean current measured on an electro-dynamometer.

V = potential at terminal of lamps.

r = ohmic resistance of lamp when hot.

L = coefficient of self-induction.

T = half period of a complete alternation.

Efficiency of Dynamos

Commercial efficiency = $\frac{\text{Electrical energy in external circuit.}}{\text{Mechanical energy applied at dynamo.}}$

Efficiency of conversion = $\frac{\text{Total electrical energy}}{\text{Mechanical energy applied at dynamo.}}$

Electrical efficiency = $\frac{\text{Electrical energy in External circuit.}}{\text{Total electrical energy}}$

The insulation of the various parts of a dynamo is a point of importance, in particular, measurements should be made of the insulation resistance between the terminals of the machine and its metal bed-plate, and between the segments of the collector and the axle.

In order to determine the efficiency of a dynamo, measurements should be made of the horse-power expended at the pulley (which may be done by means of a Prony brake) and of the energy of the electric currents given out. A good dynamo should have a commercial efficiency of at least 80 per cent.

Transformers or Converters.

Transformers are used for reducing the high potential from a dynamo to a low potential for working the lamps, the electric power being transmitted more economically at a high than a low potential, as conductors of small diameter can be used, whilst the danger of a high potential in the consumers' houses is avoided.

The efficiency of a good transformer at full output is about 96 per cent and at one-third output 90 per cent. The weight of a transformer varies from 15 to 50 lb. per horse-power according to the size and type.

The rate of alternation of the current in a transformer varies from about 50 to 130 complete alternations per second. Each type of transformer has its best rate of alternations to give the highest efficiency; if this rate is exceeded or reduced an abnormal rise of temperature takes place.

Transformers are usually made to transform from a potential of 2,000 volts or 1,000 volts down to 100 or to 50 volts.

Great care must be taken in the construction of transformers to avoid any leakage from the primary to the secondary circuit.

The following gives dimensions, &c., of a Westinghouse transformer.—

Primary current, 1.5 amperes at 1,000 volts.

Secondary „ 37.5 „ „ 40 „

Outside dimensions, 20 x 6 x 4 inches.

Weight of primary wire, 5 lb. gauge, 35 mils.

„ „ secondary „ 5½ „ „ 120 „

The secondary wire is divided into 25 sections joined in parallel.

Weight of iron, 50 lbs.

Efficiency, 97.2 per cent. (?)

ELECTRIC LAMPS.*Arc Lamps.*

If L = lighting power.

C = current.

$$L \propto 100 \left\{ C + \left(\frac{C}{4} \right)^2 \right\} - 200$$

Arc lamps for a given expenditure of energy give 7 times the power of an incandescent lamp.

If L = length of arc in millimetres.

E = electromotive force between the carbons.

C = current flowing.

R = resistance of arc.

$$R = \frac{39}{C} + 1.8 \frac{L}{C}$$

In an arc lamp the top or positive carbon burns $1\frac{1}{4}$ inches per hour, and twice as fast as the bottom or negative carbon.

A 1000 c.p. lamp requires carbons about $\frac{2}{16}$ ths inch diameter; it is usually run at a potential of 50 volts, takes about 10 amperes; the power required is about 1100 watts. Arc lamps are usually run in series.

Incandescence Lamps.

A 16 c.p. incandescent lamp is usually run at a potential of 100 volts, and takes 5 amperes, i.e., requires a power little over 3 watts per candle.

1 indicated horse-power will run 8 incandescent lamps of 16 c.p.

Incandescence lamps are usually run in multiple arc.

RULES AND REGULATIONS

Of the Institution of Electrical Engineers for the Prevention of Fire Risks arising from Electric Lighting (1887)

Conductors

1. They must have a sectional area and conductivity proportioned to the work they have to do that, if double current proposed is sent through them, the temperature of such conductors shall not exceed 150° F.

2. The conductors, or their casings, should be placed in sight if possible; and they should always be as accessible as circumstances will permit.

3. Within buildings they should all be insulated; and this rule applies equally to all conductors and parts of fittings which may have to be handled.

4. Whatever insulating material is employed, it should not soften until a temperature of 170° F. has been reached, and in all cases the material must be damp-proof.

5. When leads pass through roofs, floors, walls, or partitions, and where they cross or are liable to touch metallic substances, such as bell wires, iron girders, or pipes, they should be thoroughly protected by suitable additional covering, and where they are liable to abrasion from any cause, or to the depredations of rats or mice, they should be encased in some suitable hard material.

6. In the case of portable fittings with which flexible leads are used, special precautions must be taken.

7. Conductors should be kept as far apart as circumstances will permit the spacing between them being governed by their potential difference.

8. When conductors are carried in very inflammable structures, precautions should be taken to isolate them therefrom.

9. Conductors which are protected on the outside by lead, or metallic armour of any kind, require the greatest care in fixing, on account of the large conducting surface which would become connected to the core in the event of metallic contact between them.

10. In cases where conductors pass into a building, from one building to another, or from one room to another, precautions should be taken to prevent the possibility of fire or water passing along the course of the conductors.

11. All joints must be mechanically and electrically perfect, to prevent heat being generated at these points. When soldering fluids are used in making joints, the latter should be carefully washed and dried before insulation is applied.

12. Under all circumstances complete metallic circuits must be employed. Gas and water pipes must never form part of the circuit, as their joints are rarely electrically good and therefore become a source of danger.

13. Overhead conductors, whether passing over or attached to buildings, must be insulated at their points of support. Precautions must be taken to obviate all risk of short-circuiting where they are likely to touch a building or other overhead conductors and wires, either by their own falling or by being fallen upon by other conductors.

14. In the case of overhead wires, every main should have a lightning protector at each point where it enters or branches into a building.

15. Metal fastenings for fixing conductors should be avoided.

but, when unavoidable, some additional covering should protect the conductor from mechanical injury at such fixing points.

16. The insulation of a system of distribution should be such that the greatest leakage from any conductor to earth (and, in case of parallel working, from one conductor to the other, when all branches are switched on, but the lamps, motors, &c., removed), does not exceed one five-thousandth part of the total current intended for the supply of the said lamps, motors, &c.; the test being made at the usual working electromotive force.

17. It will often be found a great convenience and assistance in the prevention of accidents if the positive lead be coloured differently to the negative, or made otherwise distinguishable.

Switches.

18. Every switch or commutator should be of such construction as to comply with the following condition, namely.—That, when the handle is moved or turned to and from the positions of "on" and "off," it is impossible for it to remain in any intermediate position, or to permit of a permanent arc, or heating.

19. The handles of every switch must be completely insulated from the circuit.

20. The main switches of a building should be placed as near as possible to the point of entrance of the conductors, or to the generators of the current if they are within the building itself. Switches should be provided on both leads.

21. Switch-boards should bear clear instructions for their use by the inexperienced.

Electrical Fittings Generally.

22. Switches, commutators, lamps, &c., must be mounted on non-inflammable bases. Cut-outs mounted on bases of wood are inadmissible. Vulcanite bases are admissible. The cracking of porcelain is a source of danger which should be avoided. Fixings should be made in a secure manner.

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so situated within its frame that the fused metal cannot fall where it may cause a "short-circuit" or an ignition.

25. For all main conductors a cut-out should be provided for both the "flow" and "return," and the two fusible sections must not be in the same compartment.

26. The flexible leads of portable fittings must in all cases be protected by cut-outs at their fixed points of connection.

Arc Lamps.

27. Arc lamps must always be guarded by lanterns or netted globes, so as to prevent danger from ascending sparks and from falling glass and incandescent pieces of carbon.

28. All parts of the lamps and lanterns which are liable to be handled (except by the persons employed to trim them) should be insulated.

The Dynamo.

29. The armatures and field-magnet coils should be thoroughly insulated. Dynamos should always be fixed in dry places, and they must not be exposed to dust flyings or other industrial waste products carried in suspension in the air. They should not be permitted in the working-rooms of mills, where the liability to such dangers exists, or where any inflammable manufactures are carried on or inflammable materials are stored.

30. Motors should be subject to the same conditions; but when it is necessary to use them in positions such as those above referred to, they must be securely cased in, such cases having a non-combustible lining.

Batteries.

31. Both primary and secondary batteries should be placed and used under the same precautions as prescribed for dynamos, and the room in which they are placed should be well ventilated. The batteries themselves must be well insulated.

Transformers.

32. When these are used to transform either direct or alternating currents of high electro-motive force—that is, from or to an electro-motive force of, say, 200 volts—they, together with their switches and cut-outs, must be placed in a fire- and moisture-proof structure—preferably outside the building in which they are required. No part of such apparatus should be accessible except to the person in charge of their maintenance.

33. In all cases conductors conveying currents of

electro-motive force inside buildings must be exceptionally insulated, cased in, and the case proof.

34. The positive and negative terminals and conductors should not be permitted to be nearer than 12 inches.

35. Transformers which, under normal conditions, heat above 150° F., should not be permitted to run.

36. Transformers should be so constructed that in circumstances whatever should a contact between primary and secondary coils lead the high E. M. F. into the

Maintenance.

37. The value of frequently testing and inspecting apparatus and circuits cannot be too strongly urged as a precaution against fire. Records should be kept so that any gradual deterioration of the system may be detected.

38. Cleanliness of all parts of the apparatus is essential to a good maintenance.

39. No repairs or alterations must be made when the system is "on."

Three-Wire System.

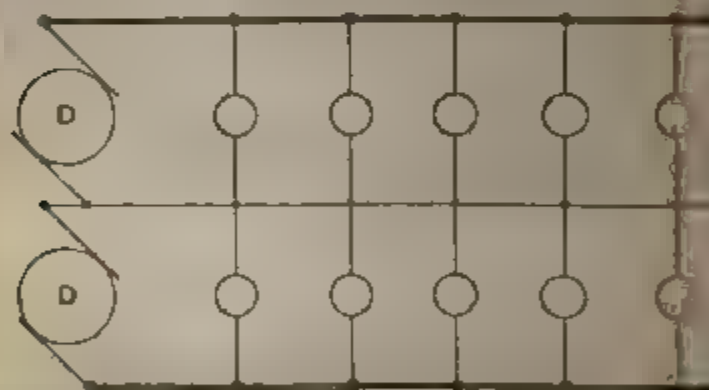


FIG. 60.

In this system of distribution, two equal dynamos are joined in series. Three lead-wires are used, two of larger sectional area than the third, i. e. centre wire. The advantage of the arrangement is that the main wires are smaller than would be the case if a single dynamo were used and all the lamps were in parallel, whilst by the use of the third or centre wire the breakage of one of the lamps does not cause the extinction of the other lamps, as they are in series, the continuity of the current is maintained by the centre wire.

Electric Motors.

Let E = electro-motive force of dynamo.

e = back electro-motive force of motor.

V = potential difference between terminals of dynamo.

V = " " " " " motor.

r_1 = Resistance of dynamo.

r_2 = " " " motor.

R = " " " line.

W_1 = mechanical work put into dynamo.

W_2 = electrical " given out by "

w_1 = mechanical " taken out of motor

w_2 = electrical " put into "

w_3 = " " available in "

$$E = V + Cr_1$$

$$E = V + C(r_1 + R)$$

$$e = V - Cr_2$$

$$C = \frac{E - e}{r_1 + R + r_2}$$

$$w_2 = CV \text{ watts}$$

$$w_3 = Ce = C(V - Cr_2) \text{ watts}$$

$$W_2 = CE \text{ watts}$$

$$\text{Maximum possible electrical efficiency of system} = \frac{e}{E}$$

$$\text{Actual electrical efficiency} = \frac{w_1}{C(V + C(r_1 + R))}$$

$$\text{Actual mechanical efficiency} = \frac{w_1}{W}$$

In order to get the greatest possible efficiency the value of e should be as large as possible, *i.e.*, the motor should run at as high a speed as possible, and in order to get as much power as possible with high efficiency E should be as large as possible.

The greatest amount of work is got out of the motor when it runs at such a speed that $e = \frac{E}{2}$. But in this case the efficiency is only 50 per cent., *i.e.*, only half the power given out by the dynamo generator is utilised in the motor. If the motor runs at a higher speed, the work it does becomes less, but its efficiency increases. When the speed becomes such that e nearly equals E , the work done is small, but it is nearly all being utilised.

Electric Light Cables.

TABLE 337.—ELECTRIC LIGHT CABLES: WEIGHTS, SIZES, AND RESISTANCES. (SILVERTOWN LIST.)

No. and.	Legal Stand- ard Gauge of each Wire.	Diameter.		Equivalent to Solid Wires.		Weight of Conductor.		Resistance at 60° Fahr.	
		Of the Strand.		Diameter.		Area.		Per Statute Mile.	
		Inch.	m/m.	Inch.	m/m.	Sq. In.	Square m/m.	Per Statute Mile.	Per Kilo- metre.
22		.028	.711	.028	.711	.0006	0.397	72.52	45.03
21		.032	.813	.032	.813	.0008	0.518	55.53	34.50
		.036	.914	.036	.914	.0010	0.656	48.87	27.26
		.040	1.02	.040	1.02	.0012	0.810	35.53	22.07
		.048	1.22	.048	1.22	.0018	1.107	24.68	15.33
		.056	1.42	.056	1.42	.0024	1.588	18.13	11.26
		.064	1.62	.064	1.62	.0032	2.075	13.88	8.624
		.072	1.83	.072	1.83	.0040	2.626	10.47	6.810
15		.080	2.03	.080	2.03	.0050	3.242	8.884	5.620
14		.092	2.34	.092	2.34	.0066	4.287	6.718	4.174
13		.104	2.64	.104	2.64	.0086	5.480	5.267	3.293
12		.116	2.94	.116	2.94	.0105	6.774	4.225	2.625
11		.128	3.25	.128	3.25	.0128	8.302	3.470	2.166
10		.144	3.65	.144	3.65	.0162	10.50	2.742	1.703
9		.160	4.06	.160	4.06	.0201	12.97	2.221	1.380
8		.020	.508	.034	.863	.0009	0.585	46.79	29.07
25		.024	.609	.042	1.06	.0014	0.893	32.50	20.10
8		.028	.711	.049	1.24	.0019	1.216	23.87	14.83
7		.020	.508	.053	1.35	.0022	1.428	20.01	12.48
23		.024	.609	.064	1.62	.0032	2.075	18.89	8.030
7		.028	.711	.075	1.90	.0044	2.849	10.20	6.837
22		.030	.762	.080	2.03	.0050	3.242	8.898	5.626
7		.033	.838	.088	2.28	.0061	3.928	7.842	4.601

TABLE 587 (continued).

Number of Wires in Strand	Legal Size and Gauge of each Wire	Diameter of each Single Wire		Diameter of the Strand		Equivalent to Solid Wire		Weight of Cable		Resistance at 60° F.	
		Inches		Inches		Inches		Per Statute Mile		Per Statute Mile	
		Inch.	in/100	Inch.	in/100	Inch.	Sq. In.	Lbs.	Kilograms	Ohms	Ohms
7	20	.036	9.14	.108	7.4	.49	.0072	14	42	.015	3.83
7	19	.040	1.02	.120	3.04	2.71	.0089	18	52	.002	3.079
7	18	.048	1.22	.144	3.66	3.25	.0128	262	71	.003	2.68
7	17	.050	1.42	.168	4.27	3.78	.0174	356	100	.002	1.85
7	16	.054	1.68	.192	4.88	4.34	.0229	465	133	.001	1.13
7	15	.072	1.83	.216	5.49	4.87	.0288	589	166	.001	.9580
7	14	.080	2.03	.240	6.10	5.41	.0356	727	205	.001	.755
10	20	.036	.914	.108	4.5	4.03	.0198	40	1.3	.001	1.404
10	19	.040	1.02	.120	5.08	4.47	.0218	496	140	.001	1.187
10	18	.048	1.22	.144	5.69	5.35	.0349	75	201	.001	.797
10	17	.050	1.42	.168	6.10	6.27	.0479	973	274	.001	.704
10	16	.064	1.68	.216	8.12	7.15	.0724	1,370	354	.001	.447
10	15	.072	1.83	.240	9.14	8.05	.0789	1,505	453	.001	.3512
10	14	.080	2.03	.264	10.16	8.94	.0978	1,906	539	.001	.2845
10	13	.102	2.64	.360	11.6	10.7	.1382	2,602	740	.001	.2151
10	12	.104	2.64	.360	13.2	11.0	.1637	3,354	945	.001	.1683
10	11	.104	2.64	.360	14.8	11.0	.1637	3,354	945	.001	.1683
10	10	.104	2.64	.360	16.4	11.0	.1637	3,354	945	.001	.1683
10	9	.104	2.64	.360	18.0	11.0	.1637	3,354	945	.001	.1683
10	8	.104	2.64	.360	20.0	11.0	.1637	3,354	945	.001	.1683
10	7	.104	2.64	.360	22.0	11.0	.1637	3,354	945	.001	.1683
10	6	.104	2.64	.360	24.0	11.0	.1637	3,354	945	.001	.1683
10	5	.104	2.64	.360	26.0	11.0	.1637	3,354	945	.001	.1683
10	4	.104	2.64	.360	28.0	11.0	.1637	3,354	945	.001	.1683
10	3	.104	2.64	.360	30.0	11.0	.1637	3,354	945	.001	.1683
10	2	.104	2.64	.360	32.0	11.0	.1637	3,354	945	.001	.1683
10	1	.104	2.64	.360	34.0	11.0	.1637	3,354	945	.001	.1683

For insulating wires india-rubber is preferable to gutta percha, as the latter gets soft when heated. Vulcanized rubber may be raised 200° without becoming deteriorated.

A good electrical and mechanical insulation is given by covering the conductors with pure india-rubber, then vulcanized india-rubber, then india-rubber-coated tape, the whole being vulcanized together, and finally covered with braided tarred flax, and a coating of preservative compound. It is false economy to use any but the very best insulation. For low tension currents (up to 100 volts) the coverings should be such as to give an insulation to the wires of not less than 1,000 megohms per statute mile; for high tension currents (above 100 volts), the insulation should be as high as 5000 megohms per statute mile. It should be distinctly understood that should the cable whose insulation should normally be 5,000 megohms, test as low as 1,000 megohms, it would not do to use this for a low tension circuit, as the lowness of the insulation would not be due to the nature of the insulating material *but to a defect in it*, which defect would be almost certain to become worse in time. The cables should be tested in water at 75°, after immersion for at least 24 hours, a battery of about 400 to 500 volts being used. Tests as to insulation are perfectly useless unless carried out in a thorough manner.

According to the Board of Trade Regulations, the size of the conductor must be such that the maximum current which may have to pass does not exceed 2,000 ampères per square inch, the wire being of pure copper or its equivalent.

Calculation of Size of Conductor.

To calculate the size of conductor required, let—

p = greatest percentage of fall of E.M.F. along conductor which is to be allowed,

E = E.M.F. at dynamo terminals,

A = maximum number of ampères per square inch wire can safely carry,

c = current wire is required to carry;

then if length of circuit *exceeds*

$$\frac{pE \times 400}{A} \text{ yds.,}$$

to calculate the sectional area (a) which the lead must have, use the formula

$$a = \frac{c}{\frac{pE \times 400}{A}} \text{ sq. ins.}$$

If the length of the circuit is *less than*

$$\frac{pE \times 400}{A} \text{ yds.,}$$

calculate from the formula $a = \frac{c}{A}$ sq. ins.

Telegraph and Telephone Wire.

TABLE 338.—RELATIVE DIMENSIONS, LENGTHS, RESISTANCES (AT 60° F.), AND WEIGHTS OF
PURE SOFT COPPER WIRE

(4lover.)

B & G. No.	Diam. Mils.	Area Sq. In.	Lbs. per Foot.	1 lb. per Mile.	Feet per Lb.	Miles per 1 l.	Feet per Ohm.	Ohms per foot.	Ohms per Mile.	Ohms per Lb.
0000	45.1	1619	.6239	3294	1.613	.0003036	19860	.0005008	2644	.0008027
000	42.5	1419	.5408	2887	1.829	.0003464	17497	.0005715	3018	.0009046
00	38.0	1134	.4371	2308	2.288	.0004333	13988	.0007149	3775	.0011636
0	34.0	9079	.3499	1848	2.858	.0005412	11198	.0008980	4717	.0012552
1	30.0	7069	.2721	1438	3.611	.0006952	8718	.001147	6056	.0014210
2	28.4	6385	.2442	1289	4.096	.0007557	7814	.001280	6758	.0015242
3	25.0	5269	.2031	1072	4.925	.0009327	6498	.001539	8125	.0017579
4	23.8	4449	.1715	905.3	5.859	.001105	5487	.001822	9623	.002063
5	22.0	3801	.1465	773.6	6.826	.001293	4689	.002133	1126	.002456
6	20.3	3237	.1247	658.6	8.017	.001518	3992	.002506	1323	.002908
7	18.0	2545	.09808	517.8	10.20	.001931	3139	.003186	1682	.003249
8	16.5	20188	.08241	435.1	12.13	.002208	2637	.003792	2002	.004001
9	14.8	01.20	.06931	350.1	15.08	.002856	2122	.004713	2488	.005108
10	13.4	01.10	.05435	287.0	18.40	.003485	1739	.005745	3036	.01038
11	12.0	01.11	.04359	240.2	22.94	.004345	1394	.00709	3785	.01640
12	10.9	009331	.03596	189.5	27.81	.005260	1151	.008689	4589	.02416
13	9.50	.007082	.02732	144.2	36.60	.006933	874.8	.01144	6039	.04187

TABLE 332.—RELATIVE DIMENSIONS, LENGTH, RESISTANCES (AT 60° F.), AND WEIGHTS OF PURE SOFT COPPER WIRE—continued.

B. & W. G. No.	Dian. Mils.	Area Sq. In.	Lbs. per Foot	Lbs. per Mile	Feet per Lb.	Miles per Ft.	Feet per Ohm	Ohms per foot.	Ohms per Mile	Ohms per Lb.
14	83.0	.005411	.02085	110.1	47.95	.000082	667.3	.01498	7.912	.07186
15	72.0	.004072	.01569	82.86	63.73	.01207	502.2	.001991	10.51	.1268
16	65.0	.003318	.01279	67.53	78.19	.01481	409.3	.002443	12.90	.1910
17	58.0	.002642	.01018	53.77	98.20	.01859	325.9	.003069	16.20	.3014
18	49.0	.001886	.007268	38.37	137.6	.02606	232.6	.004300	22.70	.5316
19	42.0	.001385	.005340	28.19	187.3	.03547	170.9	.005852	30.90	1.096
20	35.0	.0009621	.003708	19.58	269.7	.05108	149.4	.008427	44.49	2.273
21	32.0	.0008043	.003100	16.37	322.6	.06110	99.20	.01008	53.23	3.952
22	28.0	.0006158	.002373	12.53	421.4	.07981	75.95	.01317	69.52	5.548
23	25.0	.0004909	.001892	9.989	528.6	.1001	60.54	.01652	87.21	8.730
24	22.0	.0003801	.001465	7.730	682.6	.1293	46.89	.02134	112.6	14.56
25	20.0	.0003142	.001211	6.393	825.9	.1564	38.75	.02581	130.3	21.31
26	18.0	.0002545	.0009808	5.178	1020	.1931	31.39	.03186	168.3	32.49
27	16.0	.0002011	.0007749	4.092	1290	.2444	24.80	.04032	212.9	52.04
28	14.0	.0001539	.0005933	3.133	1685	.3192	18.99	.05267	278.1	88.77
29	13.0	.0001327	.0005116	2.701	1955	.3702	16.37	.06108	322.5	110.4
30	12.0	.0001131	.0004359	2.362	2294	.4345	13.95	.07169	378.6	164.5

TABLE 339.—HARD COPPER TELEGRAPH WIRE.

(Post Office Specification.)

Weight per Statute Mile.			Approximate Equivalent Diameter			Minimum Breaking Weight.	Minimum Number of Twists in 3 Ins.	Maximum Resistance per Mile at 60° F.	Minimum Weight of each Coil of Wire.
Required Standard.	Min. diam.	Max. diam.	Stand. angl.	Min. diam.	Max. diam.				
Lbs.	Lbs.	Lbs.	Mils.	Mils.	Mils.	Lbs.		Ohms.	Lbs.
100	97½	102½	79	78	80	330	30	9.1	50
150	146½	153½	97	95½	98	480	25	6.05	50
200	195	205	112	110½	113½	650	20	4.53	50

The wire must be capable of being wrapped, in six turns, round its own diameter, unwrapped, and again wrapped in six turns round its own diameter in the same direction as the first wrapping, without breaking.

When aerial copper wires are used for telegraphic purposes, resin should be employed as a flux in making joints, and too much heat should not be applied, as it softens the wire and weakens its tensile strength at that point.

Samples taken from coils of the 800-lbs. wire should bear bending round a bar 2½ inches diameter without any signs appearing of the zinc cracking or peeling off, the 600-lbs. wire should similarly bear bending round a bar 2½ inches in diameter; the 450-lbs. and 400-lbs. wire round a bar 2 inches in diameter, the 200-lbs. wire round a bar 1½ inches in diameter.

Iron Telegraph Wire

(page 630)

Test of Galvanizing.—Take samples from coils and plunge them into a solution of sulphate of copper saturated at 60°; allow them to remain in solution 1 minute then withdraw and wipe clean. The galvanizing should permit of this process being 1 times performed with each sample without there being any sign of a reddish deposit of metallic copper on the wire, which would be the case if the coating of zinc were too thin. See also page 633.

TABLE 340.—GALVANIZED IRON TELEGRAPH WIRE.

(Post Office Specification.)

Dimension	Required Standard.	Allowed		Weight per M.L.		Tests for Strength and Ductility.				Maximum Resistance per Mile of the Standard Size at 60° Fahr	Constant, being Standard Weight & Resistance		Weight of each piece of C. I. of Wire		Weight of each Bundle	
		Minimum	Maximum	Required Standard	Allowed	Minimum Breaking Weight	Minimum Number of Twists in 6 Inches.	For Breaking Weight not less than	Minimum Number of Twists in 6 Inches.				Minimum	Maximum	Minimum	Maximum
Md. 24	24	180	247	80	1.88	2,480	13	2,530	14	13	5,400	5,400	Lbs. 90	Lbs. 120	Lbs. 90	Lbs. 120
Md. 21	21	180	214	60	1.62	1,860	17	1,910	18	15	5,400	5,400	Lbs. 90	Lbs. 120	Lbs. 90	Lbs. 120
Md. 18	18	180	180	45	1.47	1,390	19	1,425	18	17	5,400	5,400	Lbs. 90	Lbs. 120	Lbs. 90	Lbs. 120
Md. 15	15	175	175	40	1.24	1,240	21	1,270	20	19	5,400	5,400	Lbs. 90	Lbs. 120	Lbs. 90	Lbs. 120
Md. 12	12	120	120	20	1.13	620	30	648	28	26	5,400	5,400	Lbs. 45	Lbs. 65	Lbs. 80	Lbs. 100

Sags and Tensions for Suspending Wires.

The tension when the temperature is lowest, *i.e.*, when the strain is greatest, should not exceed $\frac{1}{4}$ th of the breaking strain.

The sag varies with the material, but not with the gauge ; the tension varies directly with the weight per foot of the wire.

$$d = \frac{l^2 w}{8t}; \quad d = \sqrt{\frac{3l(L-l)}{8}}; \quad L = l + \frac{8d^2}{3l}; \quad t = \frac{l^2 w}{8d}.$$

where

l = span ;

w = weight of unit length ;

d = sag (or dip) ;

L = length of wire in span ;

t = tension ;

also,

w for 400 lbs. iron = .075758 lb. per foot.

„ 150 „ copper = .028409 „ „

„ 100 „ „ = .018939 „ „

and

Coefficient of expansion for iron = .00000683 per deg. F.

Coefficient of expansion for copper = .00000956 „ „

TABLE 341.—SAGS AND TENSIONS TO BE OBSERVED IN ERECTING WIRES AT VARIOUS TEMPERATURES.

400-lbs. Iron Wire (No. 7½).

Span.	22° F. Low Winter Temperature.			40° F. Ordinary Winter Temperature.			58° F. Average Summer Temperature.			76° F. High Summer Temperature.		
	Sag.		Ten- sion.	Sag.		Ten- sion.	Sag.		Ten- sion.	Sag.		Ten- sion.
Yards.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.
100	3	1¾	270	3	9	227	4	3¼	200	4	8⅞	180
90	2	6⅞	270	3	1¾	219	3	2¾	190	4	0⅞	169
80	2	0¼	270	2	7⅞	210	3	0¾	178	3	5⅞	157
70	1	6½	270	2	1¼	198	2	6½	164	2	10⅞	143
60	1	1⅞	270	1	8	184	2	0¾	148	2	4¾	129
50	0	9½	270	1	3½	165	1	7¾	130	1	11¼	117

TABLE 341.—TABLE OF SAGS, ETC. (*continued*).
150-lbs. Hard-drawn Copper Wire (No. 12½).

Yards.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.
100	2	8	120	3	7	89	4	3½	74	4	11½	64
90	2	2	120	3	1	84	3	9½	69	4	4½	60
80	1	8½	120	2	6½	80	3	2½	64	3	8½	54½
70	1	3½	120	2	1¾	73	2	8½	57½	3	2½	49
60	0	11½	120	1	9	66	2	3½	51	2	8¼	43
50	0	8	120	1	4½	58	1	10	44	2	2½	36½

100-lbs. Hard-drawn Copper Wire (No. 14).

Yards.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.
100	2	8	80	3	7	59	4	3½	49	4	11½	43
90	2	2	80	3	1	56	3	9½	46	4	4½	40
80	1	8½	80	2	6½	53	3	2½	42½	3	8½	36
70	1	3½	80	2	1¾	49	2	8½	38	3	2½	33
60	0	11½	80	1	9	44	2	3½	34	2	8¼	29
50	0	8	80	1	4½	39	1	10	29	2	2½	24

Copper Wire.

Conductivity of Copper Wire.

$$\text{Percentage of conductivity} = \frac{l^2 \times 22.61}{w \times k \times r}$$

l = length of wire in feet.

w = weight of wire in grains.

r = resistance of wire in ohms.

k = temperature coefficient (p. 604).

Example.—The resistance of a copper wire 35 feet (l) long and weighing 297 grains (w), was .932 ohm (r), the temperature being 68° F.; what was the percentage of conductivity of the wire?

From Table, p. 604, $k = 1.015$, therefore

$$\text{Percentage of conductivity} = \frac{35 \times 35 \times 22.61}{297 \times 1.015 \times .932} = 98.6.$$

Resistance of Copper Wire.

Resistance per mile of pure soft copper wire at 60° F., d mils. in diameter = $\frac{54402}{d^2}$ ohms.

Resistance per mile of pure soft copper wire at 60° F. weighing w lbs. = $\frac{872.2}{w}$ ohms.

Weight of pure soft copper wire 1 mile long having a resistance of 1 ohm at $60^{\circ} = 872.2$ lbs.

Length in yards of pure soft copper wire having a sectional area of a sq. ins. required to give a resistance of r ohms at 60° F. $= ra \times 41,161$. If

l = length of a wire.

a = sectional area.

d = diameter.

w = weight.

r = resistance.

$$r = \frac{l}{a} \kappa = \frac{l}{d^2} \kappa' = \frac{l}{w} \kappa''.$$

Where κ , κ' , and κ'' are the resistances of a wire of unit dimensions. For pure soft copper at 60° F., if l is in feet, a in square inches, d in mils. ($\frac{1}{1000}$ th in.) and w in grains (7000 grains = 1 lb.).

$$\kappa = .000008098, \kappa' = 10.311, \kappa'' = .2190.$$

The resistance of a copper wire increases about .21 per cent. per 1° F. If

r = resistance at t° F.

R = " " T° F.

$R = r(1 + .0021(T - t))$ approximately.

" = $r(1.0020935)^{T-t}$ more exactly.

Iron Wire.

Two qualities of iron wire are used by the Postal Telegraph Department for aerial line purposes, known as low resistance and high resistance wire. The low resistance wire may consist either of "special blend" iron, giving a mean resistance of 11.3 ohms per mile at 60° F. for the standard gauge of 171 mils. (No. 7½ B. W. G.); or of "charcoal" iron, giving under the same conditions a resistance of 11.2 ohms per mile. The high resistance wire which is more generally used (see Specification, page 630) of the same gauge has a mean resistance of 12.7 ohms per mile, but is cheaper in price. The low resistance iron is used for circuits over about 200 miles in length, its breaking strain is rather less than that of the high resistance wire.

1 foot-grain of pure iron has a resistance of 1.007 ohms at 0° C (32° F.).

1 ohm-mile (a wire 1 mile long, having a resistance of 1 ohm) of pure iron, weighs 4368.94 lbs.

Ditto, low resistance blend-wire weighs 4520 lbs.

Ditto, " " charcoal " 4480 "

Ditto, high " " " 5080 "

To determine the resistance R at a temperature t° F. that (r) at a temperature t° being known

$$R = r(1.0027)^{t-t}.$$

Telegraphy.

Connections of Apparatus on the Morse System adopted by the Postal Telegraph Department.

SINGLE CURRENT SYSTEM.

DIRECT WRITER (Combination Instrument.)

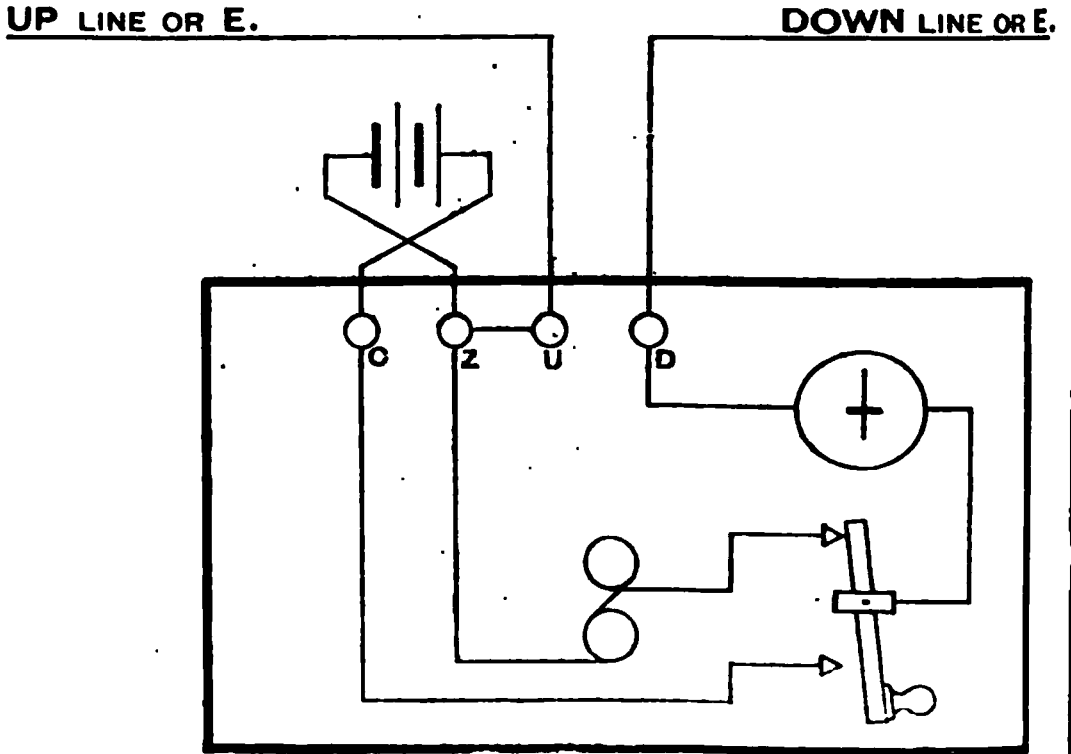


FIG. 91.

DIRECT SOUNDER OR WRITER.

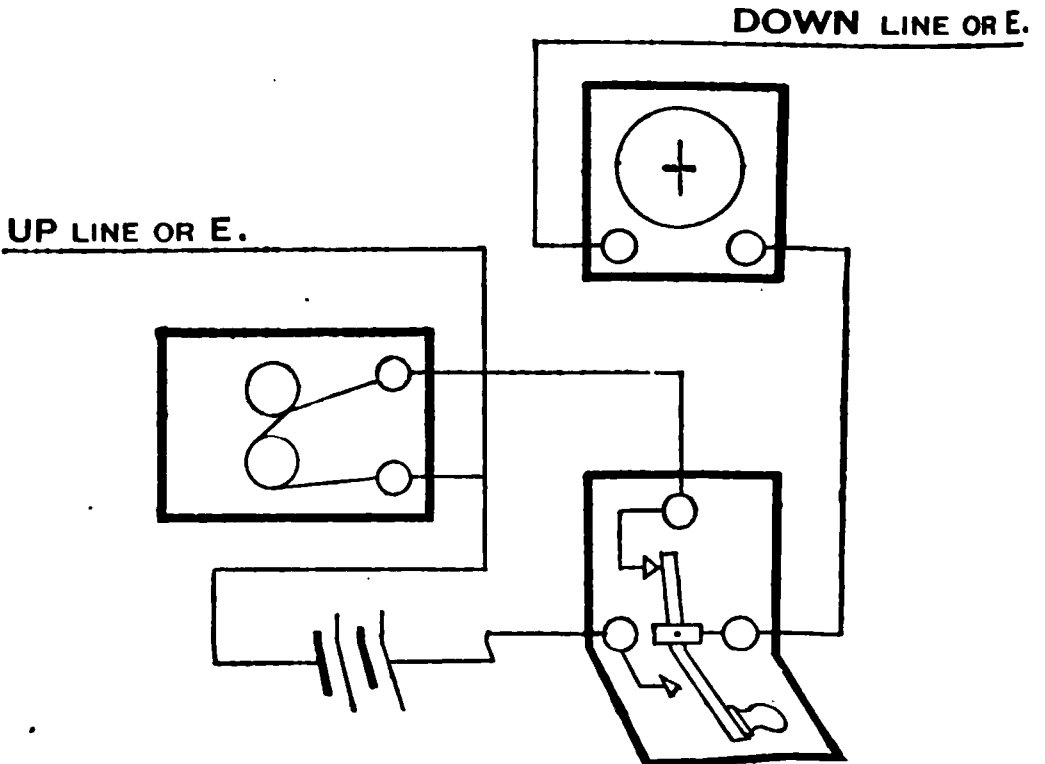


FIG. 92.

SOUNDER WITH RELAY.
DOWN LINE OR E.

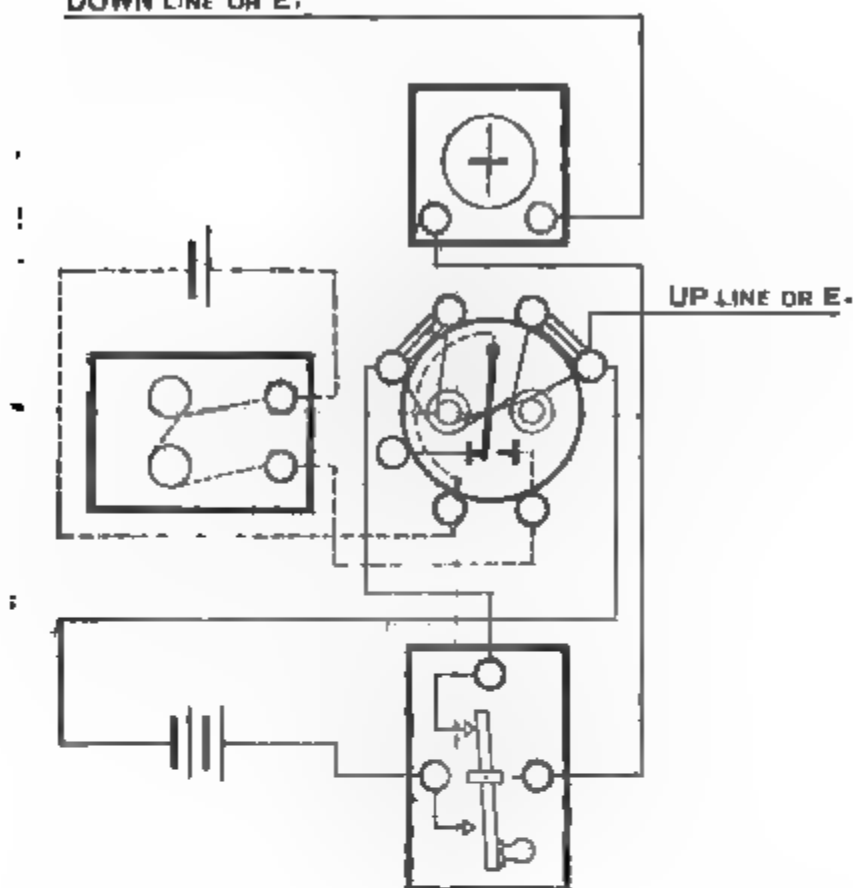


FIG. 93.

DIRECT WRITER. Duplex: with Switch.

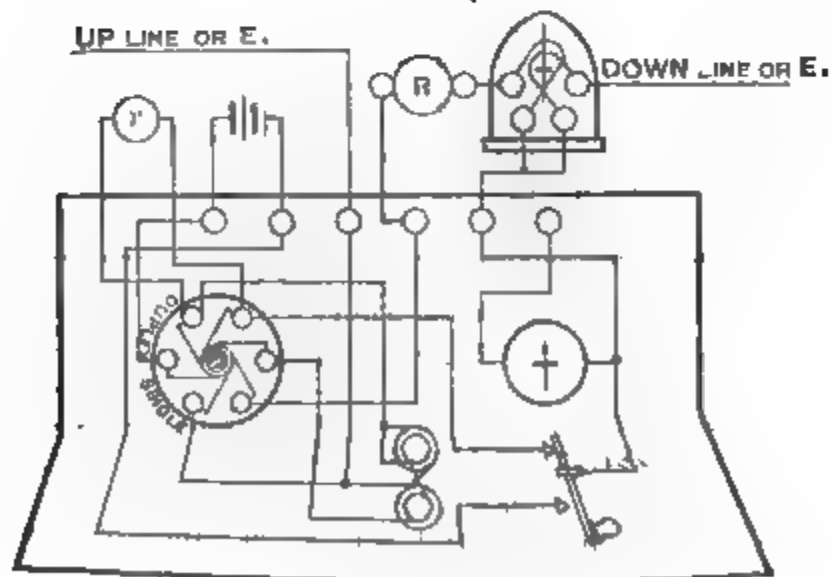


FIG. 94.

All the systems require from 15 to 20 milliamperes of current.

The Direct Writer Duplex system is suitable for circuits to about 25 miles in length. The switch is employed for the purpose of changing the connections to the arrangement for ordinary working, should the insulation of the line become such as to render a proper balance by means of the Rheostat difficult or impossible, and duplex working consequently impossible also. R is a fixed resistance equal as nearly as possible to the resistance of the battery.

TABLE 342. TELEGRAPH POLES.

SIZES OF LIGHT POLES.				SIZES OF STOUT POLES.			
Length, in Feet.	Diameter at Top, Inches.		Minimum Diameter at 5 Feet from Butt End, Inches.	Length in Feet.	Diameter at Top, Inches.		Minimum Diameter at 5 Feet from Butt End, Inches.
	Mini- mum.	Maxi- mum.			Mini- mum.	Maxi- mum.	
18	5	5 $\frac{3}{4}$	6 $\frac{1}{2}$	18	5 $\frac{1}{2}$	6 $\frac{1}{2}$	7 $\frac{1}{4}$
20	5	5 $\frac{3}{4}$	6 $\frac{1}{2}$	20	5 $\frac{1}{2}$	6 $\frac{1}{2}$	7 $\frac{1}{2}$
22	5	5 $\frac{3}{4}$	6 $\frac{3}{4}$	22	5 $\frac{1}{2}$	6 $\frac{3}{4}$	7 $\frac{3}{4}$
24	5	5 $\frac{3}{4}$	7	24	5 $\frac{1}{2}$	6 $\frac{3}{4}$	8
26	5	6	7 $\frac{1}{4}$	26	5 $\frac{3}{4}$	7	8 $\frac{1}{4}$
28	5	6 $\frac{1}{4}$	7 $\frac{3}{4}$	28	6	7 $\frac{1}{4}$	8 $\frac{3}{4}$
30	5	6 $\frac{1}{4}$	8	30	6	7 $\frac{1}{4}$	9
32	5 $\frac{1}{4}$	6 $\frac{1}{2}$	8 $\frac{1}{4}$	32	6 $\frac{1}{4}$	7 $\frac{1}{2}$	9 $\frac{1}{4}$
34	5 $\frac{1}{4}$	6 $\frac{3}{4}$	8 $\frac{3}{4}$	34	6 $\frac{1}{4}$	7 $\frac{3}{4}$	9 $\frac{3}{4}$
36	5 $\frac{1}{2}$	7	9	36	6 $\frac{1}{2}$	7 $\frac{3}{4}$	10
38	5 $\frac{1}{2}$	7	9 $\frac{1}{4}$	38	6 $\frac{1}{2}$	7 $\frac{3}{4}$	10 $\frac{1}{4}$
40	5 $\frac{1}{2}$	7 $\frac{1}{4}$	9 $\frac{3}{4}$	40	6 $\frac{1}{2}$	8	10 $\frac{3}{4}$
45	7 $\frac{1}{4}$	7 $\frac{1}{2}$	10 $\frac{1}{2}$	45	6 $\frac{3}{4}$	8 $\frac{1}{2}$	11 $\frac{1}{2}$
50	6	7 $\frac{1}{4}$	11 $\frac{1}{4}$	50	7	8 $\frac{3}{4}$	12 $\frac{1}{4}$
55	6	8	12	55	7 $\frac{1}{4}$	9	13
60	6	8	12 $\frac{1}{2}$	60	7 $\frac{1}{2}$	9	13 $\frac{1}{2}$

Telegraphic Solder.

Equal parts by weight of ingot tin and pig lead.

Materials and Tools for constructing a 300-Mile Iron Pole Telegraph Line of 1 Wire.

Materials.

6,000 iron tubular and conical telegraph poles attached

base pile for driving, the pole complete not weighing more than 100 lbs. ; length over all when jointed 18 ft. Length of cast iron base pile about 4 ft., and tube about 14 ft. 6 in., with slit-joint between base pile and tube.

6,000 soft iron rings for caulking into base plate.

6,000 lightning rods, 18 ins. long, to surmount poles.

6,150 insulators, Cordeaux pattern.

4 Hand rammers, for driving base piles.

14 tons No. 14 hand-drawn copper wire, 103 lbs. to the mile, 340 lbs. breaking strain ; resistance about 8 ohms per mile.

$\frac{3}{4}$ cwt. best tin solder ; 4 gals. soldering solution in gallon jars.

250 anchor plates, stay-rods, stay-wires, clips, &c., complete, for angle poles.

2 $\frac{1}{2}$ cwt. No. 18 soft copper wire for binding wire to insulator.

$\frac{1}{2}$ cwt. No. 20 tinned copper wire for jointing line wire.

1 wire dynamometer vice for copper wire.

Construction Tools.

3 pairs small-draw vices and keys for No. 14 copper wire.

2 pairs devil's claws.

2 fire-pots.

6 8-in. cutting-pliers.

3 10-in. flat bastard files.

6 soldering-irons, large.

2 tool baskets.

12 lbs. lump sal-ammoniac.

3 large hammers.

2 sledge-hammers.

6 steel wedges.

1 2-ft. rule.

6 Picks, handled.

6 shovels.

6 spades.

3 jumpers.

2 iron punners, handled.

2 crow-bars, steel-pointed.

2 wire-drums and barrows, light and portable.

3 bill-hooks.

3 15-ft. wooden ladders.

3 American axes.

2 hand-saws.

2 saw-files.

2 screw-hammers.

Telephones.

Distance over which *good* speaking is possible :—

	KR.
Overhead copper wires . . .	10,000
Cables and underground . . .	8,000
Overhead iron wires . . .	5,000

where KR is the product of the *Total Inductive Capacity* and the *Total Conductor Resistance* of the Line. If the value of KR exceeds the values given, the speaking commences to become difficult.

Through underground Wire No. 18 Copper and No. 7½ Gutta-percha, the *good*-speaking limit is about 36 miles.

If the working is carried on through a looped wire *with no earth used*, the value KR (*i.e.*, the capacity of the whole length of wire multiplied by the total resistance of the whole length of wire) must be divided by 4, to give the working value of the loop.

Lightning Conductors.

CODE OF RULES FOR THE ERECTION OF LIGHTNING
CONDUCTORS (*Lightning Rod Conference*).

Points.—The point of the terminal should not be sharp, not sharper than a cone of which the height is equal to the radius of its base. But a foot lower down a copper ring should be screwed and soldered on to the upper terminal, in which ring should be fixed three or four sharp copper points, each about 6 in. long. It is desirable that these points be so platinized, gilded, or nickel-plated, as to resist oxidation.

Upper Terminals.—The number of conductors or points to be specified will depend upon the size of the building, the material of which it is constructed, and the comparative height of the several parts. No general rule can be given for this ; but the architect must be guided by circumstances. He must, however, bear in mind that even ordinary chimneys, when exposed, should be protected by short terminals connected to the nearest rod, inasmuch as accidents often occur owing to the good conducting power of the heated air and soot in a chimney.

Insulators.—The rod is not to be kept from the building by glass or other insulators, but attached to it by metal fastenings.

Fixing.—Rods should preferentially be taken down the side of the building which is most exposed to rain. They should be held firmly, but the holdfasts should not be driven so tightly as to pinch the rod, or prevent the contraction and expansion produced by changes of temperature.

Factory Chimneys. These should have a copper band round the top, and stout, sharp, copper points, each about 1 ft. long, at intervals of two or three feet throughout the circumference, and the rod should be connected with all bands and metallic masses in or near the chimney. Oxidation of the joints must be carefully guarded against.

Ornamental Ironwork. All vanes, finials ridge ironwork &c., shall be connected with the conductor, and it is not absolutely necessary to use any other point than that afforded by such ornamental ironwork, provided the connection be perfect and the mass of ironwork considerable. As, however, there is risk of derangement through repairs, it is safer to have an independent upper terminal.

Material for Rod.—Copper, weighing not less than 6 oz. per foot run, and the conducting of which is not less than 90 per cent. of that of pure copper, either in the form of tape or rope or stout wires, no individual wire being less than No. 12 B. W. G. Iron may be used, but should not weigh less than 2½ lbs. per foot run.

Joints.—Although electricity of high tension will jump across bad joints, they diminish the efficacy of the conductor, therefore every joint, besides being well cleaned, screwed, scarfed, or riveted, should be thoroughly soldered.

Protection. Copper rods to the height of 10 feet above the ground should be protected from injury and theft, by being enclosed in an iron pipe reaching some distance into the ground.

Painting. Iron rods, whether galvanised or not, should be painted; copper ones may be painted or not according to architectural requirements.

Curvature. The rod should not be bent abruptly round sharp corners. In no case should the length of the rod between two joints be more than half as long again as the line joining them. When a stringcourse or other projecting stonework will admit of it, the rod may be carried straight through, instead of round the projection. In such a case the hole should be large enough to allow the conductor to pass freely and allow for expansion, &c.

Extensive Masses of Metal.—As far as practicable it is desirable that the conductor be connected to extensive masses of metal, such as hot-water pipes, &c., both internal and external; but it should be kept away from all soft metal pipes, and from internal gas-pipes of every kind. Bells inside well-protected spires need not be connected.

Earth Connection.—It is essential that the lower extremity of the conductor be buried in permanently damp soil; hence proximity to rain-water pipes, and to drains, is desirable. It is a very good plan to make the conductor bifurcate close below the surface of the ground, and adopt two of the following methods for securing the escape of the lightning to earth. A strip of copper tape may be led from the bottom of the rod to the nearest gas or water *main*—not merely to a lead pipe—and be soldered to it; or a tape may be soldered to a sheet of copper 3 ft. \times 3 ft. and $\frac{1}{16}$ th in. thick, buried in permanently wet earth, and surrounded by cinders or coke; or many yards of the tape may be laid on a trench filled with coke, taking care that the surfaces of copper are, as in previous cases, not less than 18 square feet. Where iron is used for the rod, a galvanized iron plate of similar dimensions should be employed.

Inspection.—Before giving his final certificate, the architect should have the conductor satisfactorily examined and tested by a qualified person, as injury to it often occurs up to the latest period of the works from accidental causes, and often from the carelessness of workmen.

Collieries.—Undoubted evidence exists of the explosion of fire-damp in collieries through sparks from atmospheric electricity being led to the mine by the wire ropes of the shaft and the iron rails of the galleries. Hence the head-gear of all shafts should be protected by proper lightning conductors.

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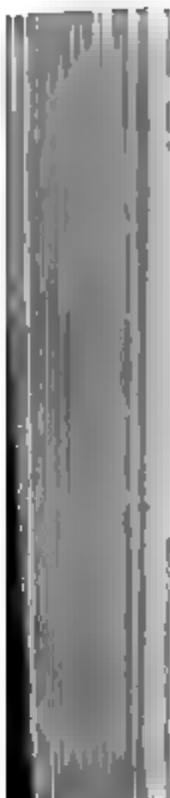
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